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THE PYRAMID BUILDERS.

By COPE WHITEHOUSE,

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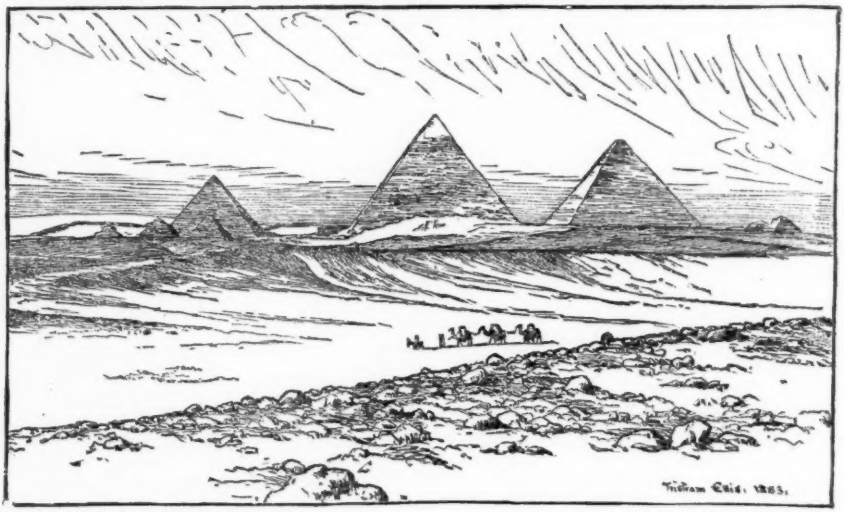
THE East and West have always been divided and opposed. The Pyrenees and Alps, or the Mediterranean, or the rampart of the Lebanon, with its tremendous counterscarp and fosse, sunk 1,300 feet below the surface of the earth, have, each in turn, been a frontier. The East never effected a lodgment in Central Europe. The West never penetrated into Arabia. The opposition is not limited to language,

religion and morals. It extends to art, architecture and engineering science. It is due to recondite causes and remote events, as well as to existing geological and geographical conditions. The characteristic of oriental life is its common sense. Men live in far closer and more friendly relation to nature than in the artificial and mechanical civilization of the West. There is less disposition to domineer over the lower forces. The power of the earthquake and the majesty of the volcano are recognized and not defied. Thus the types of religion and architecture stamped by Fusi-yama on the Japanese are much more legible than those which Ætna imposes upon the Sicilians. A rapid change of sentiment is taking place among ourselves. The two ends of Manhattan Island are laid out in conformity with the antecedent work of nature. The central portion exhibits reckless prodigality of labor with the worst conceivable results. It is a favorable sign that the period of rude self-assertion is drawing to a close. The sun and the wind are not yet worshiped, but there are statutes passed every day to secure due respect for light and air from an ignorant, greedy and gainsaying people. If the gun is still in the hands of any one, whose inferiority to the beast or bird whose life he seeks requires its elaborate mechanism, it is muzzled for a large part of the year. It kills at a few more yards than the blow-pipe of the South American, but it frightens the game to a proportionately greater distance. The discriminating bow of Æneas supplied his companions with as many selected deer as he required before the does and fawns were alarmed. An hour later

he was in the midst of Carthage, with all the turmoil of a busy manufacturing and commercial metropolis. The ancient Egyptians like the modern Chinese could snare wild fowl in their gardens. Progress in the transmission of intelligence and the exchange of products can no longer conceal the fact that we have overlooked true sources of wealth and comfort. We are impoverishing and disfiguring with frightful rapidity the domain we possess.

Although the nature-worship of the East is to some extent a superstition, yet it is also a religion. It formulates rules by which men are compelled to recognize

SMALL PYRAMIDS. THIRD PYRAMID. SECOND PYRAMID. PYRAMID OF CHEOPS. SMALL PYRAMIDS.

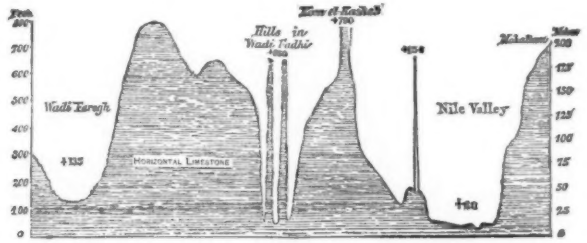


The Pyramids and Temples of Gizeh. By W. M. FLINDERS PETRIE.

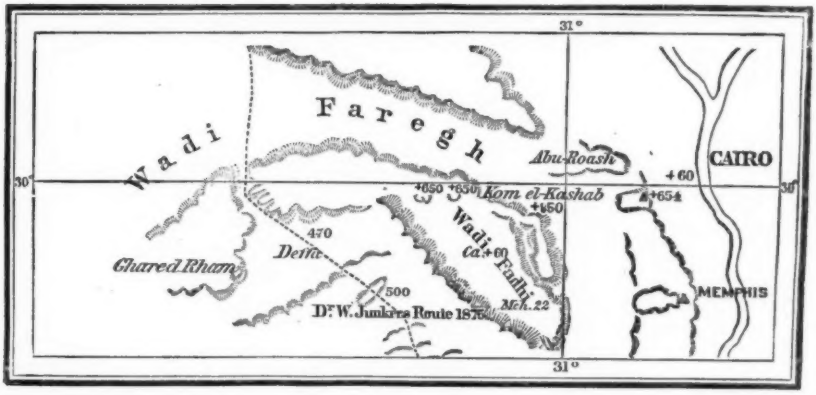
THE PYRAMID-HILL OF GIZEH FROM THE SOUTH.

that they are bound hand and foot to this planet. The definite and measurable forces of the world can be temporarily disturbed by human agency. Its more majestic powers could not be arrested for an instant by the sum total of human energy since the world began. Even where change has been effected, atoms unweariedly seek their normal state. We vex the sunbeam with an aniline dye. Straightway it seeks to restore the particles to freedom and the molecules respond by insidious movements. Steel is the favorite instrument of modern violence. The tool converts itself into crystals and snaps like a pipe stem. This is one cause of the feverish activity of modern society. We have no time to lose. The life of engineering works is, as it were, but a span long. The engine must hasten to do its work ere it die. It is not wholly the fault of the material employed. There is a wooden building at Nara in Japan, in which the Mikado's art treasures have been preserved for twelve hundred years. It has had four roofs. The third lasted five hundred years. The present tiles have been in place since 1730. There was a pyramid of sun-dried bricks on the banks of the Nile, whose age was unknown when Herodotus visited it and said that Asychis was rumored to have made it from the alluvial deposit in a reservoir. It stands there still after twenty-two hundred years. There is a dome of flat stones, corbelled out until the hemisphere was complete, beneath earth, bushes, and even trees, which is as perfect now as when the women of Argos pointed the finger of jealous scorn at the beautiful Helen. In wood, earth and stone, Asia, Africa and Europe thus show how architects may conform to the laws of earthquakes, climate and society, and thus leave enduring monuments to their tact. Comparative engineering is a new

study. The old masters teach one to suspend judgment. Prejudice speedily yields to admiration. Weight of material may cost less than more elaborate construction. Dry earth may make a better wall to keep out heat than thinner layers of burnt clay. Megalithic structures show no tool marks. But, perhaps, skill in cleavage saved the labor which would have left the traces of the instrument. This economy of force goes much farther. fied mass of soft stone, offered the cool depths of a grotto, and the deep shadows of its exterior ornament as a welcome relief to the glare and heat of a torrid sun. An artificial stream bursts from a mountain side in the heart of a town. The labor of a few days sufficed to cover the portal of the fountain with well-known signs telling to child and man that the anger of the God of Health dwelling in the shades of the distant grove would



SECTION OF FIFTY MILES ON LAT. 30°.



The architects and engineers of the ancient world strove to effect only such modifications of nature as would accomplish their purpose. The purpose was in turn defined by the material. But by material must be understood more than the granite or limestone, the clay or earth, which lay most convenient to the builders' hand. These builders also considered the presence of a ravine or hill as a gift of nature not to be lightly disregarded or destroyed. Thus in a warm dry climate the rock-hewn temple, carved in a stratismite with deadly weapon the offender against purity. A monolithic house at Amrit is one of the most interesting remains of Northern Syria. The material was cut away in such a fashion that only thin walls and partitions were left. This house was a chateau of important dimensions. The principal façade is one hundred feet long. The edifice was nearly square. The walls still retain the respectable height of twenty feet. Their thickness of thirty-two inches does not exceed that of the basement walls of a

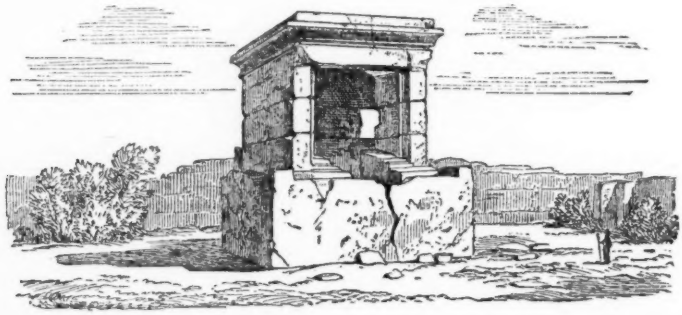
modern structure. Twenty-five centuries have elapsed since the Phœnician merchant determined to exhibit the wealth acquired, perhaps, in the tin trade with Cornwall, from a profitable but nauseous dye-house in Tyre, or the pearl fisheries of Ceylon. He built his house in the quarry, and moved the least amount of stone the shortest distance. He used the spaces separated by the live rock as chambers, and plastered without fear of settlement upon the natural walls. The interior was divided into at least three chambers by partitions left in the same way. The external wall to the north was artificial; its lowest courses are still to be found hidden in the soil, the south wall was partly rock, partly masonry. In the island to the north of Saïda the rock still bears traces of similar works. The lower parts of walls are shaped as they stand. We find them pierced in many parts with niches and rectangular or round-headed doorways. In some instances even partition walls are rock-hewn. Claudius Iolaus said, sixteen centuries ago: "When the Phœnicians began to settle on the rocky shores to which they were attracted for the sake of the purple dye, they built houses for themselves and surrounded them with trenches; as they cut the rock for this latter purpose, they used the material removed for the walls of their towns and so protected their ports and jetties." Such examples as these are to be analyzed, not imitated. They have, however, a direct bearing upon the problem of those pyramids at Gizeh, upon which such an extraordinary amount of thought has within a few years been concentrated and wasted.

MIDDLE COURSES OF THE PYRAMID OF CHEOPS.

The gorge of the Nile Valley is parallel with the Red Sea. Recent events have shown that the Upper Nile is more readily reached from Suakim than from Cairo. The stream of commerce may be taken in the flank at many points from Massowah to Suez. The British troops, under Abercromby, fought the battle of Alexandria on March 13th, 1801. They entered Egypt at Thebes. The same nation is repeating the same tactics at a more southerly point. It aims to effect a junction with troops encamped near Meraweh. The name Meraweh, or Meroe, was known to the cartographers who provided Ælius Aristides with a traveling library. It has been the current appellation of this place for more than three thousand years. Before the remotest date assignable to Buddha or the Trojan War, the same musical sounds expressed admiration for the "lovely" capital of Nubia. According to an Alexandrian tale, which was very ancient sixteen hundred years ago, it was the headquarters of Moses. His adoptive mother, Mary, in her devotion, had accompanied him to the Soudan. She died. The town he built to her memory still bears her name. Whether his campaign was undertaken to crush a Mahdi, or to confront a maritime power with its seat in the Bahrein Islands of the Persian Gulf, is obscure. But it is curious that both at Meroe and at Cairo there are groups of pyramids. Nowhere else, from the Cape of Good Hope to the Baltic are there similar structures. Two garrisons of foreign troops, separated by a thousand miles, are now watched by these mysterious sentinels. At Meroe and the sixth cataract, as at Mœris and the great gate of the Delta, these square masses with tri angular sides continue to present a difficult, if not insoluble, problem. Between these points there are many natural hills which have been used for architectural purposes. Two temples in the gritstone rock known as Aboo-Simbel, or Ipsambool, are generally considered, next to Thebes and the Pyramids, as the most interesting remains of Africa. How little labor accomplished this result! An insignificant spur juts out into the Nile. A portion of the rock has been cut away to form a façade about a hundred feet in

STRATIFICATION OF THE HILL OF GIZEH.

width and as many in height. No edifice better deserves the name of great, in its best sense of the ratio of means to purpose. The amount of material removed is less than that excavated for a common dwelling-house in New York. The stately cornice with its freize, and the four gigantic statues sixty-six feet high, did not cost as much as the brown-stone veneering of an equal superficies. These twenty-two cynocephali, the large statue of the sun-god Ra and the four collossi could be repeated at the price of a wooden spire for a village church. Yet, a steamer is kept upon the Upper Nile for the sole purpose of carrying persons of the highest education and most refined taste to see the summer's amusement of some engineer corps, who spent



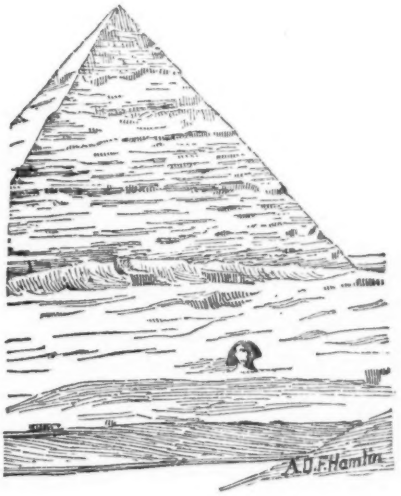
THE HISTORY OF ART IN PHŒNICIA. MM. PERROT AND CHIPIEZ.

less in perpetuating the fame and features of their monarch and his queen for thirty centuries, than any single group of travelers in getting to the spot. The façade of Ipsambool was, of course, begun at the top. The fragments of loose stone were picked off by a handful of men. Then a trench was cut across the steep face to mark the upper member. Two deep grooves were scored at either side. The Egyptian Buonarotti sat in the shade at a convenient distance, and directed with rod and voice the movements of those who split off and pried away the layers of gritstone until they had blocked out a rough draught of his idea. The material removed was as available for the purposes to which it was applied as if the quarry had been left as a scar instead of a temple. The unfinished façades of Petra prove, if evidence be required, that these Titans in design always worked downwards, not upwards. The problem would have been far more complex if the garrison of "the hill of the pure waters" had labored for years instead of weeks, on four sides instead of one, and reduced the intervening spaces to the thin walls of the Phœnician dwelling. They might have pierced the mass like the ivory ball of the Chinese, left monolithic shrines detached from floor and roof in chambers, accessible only by openings of smaller size. The Egyptian tabernacles of a single block excited the admiration of Herodotus. The same effect was obtained at Amrit, in Northern Phœnicia, without any extraordinary effort. A large quadrangle, 192 feet by 160, has been cut in the living rock. In the center, a block has been left some twenty feet square and 10 feet high. Upon this cubical mass, which is part of the actual floor of the temple, has been built a small tabernacle. It is composed of four stones. Three of them are interposed between the mass of living rock which forms the foundation, and the roof which is a monolith. This upper stone seems to have been supported originally by metal columns, forming a kind of portico. Placed one beside the other on the apex of a mass of rocks two monuments, known as El-Meghazil, dominate the surrounding country and recall the famous colossi in the plain of Thebes. "One of these monuments," says M. Renan, "is a masterpiece of proportion, elegance and majesty." They rise above a large enclosure hollowed out of the rock. Lime-

stone differs in its successive strata. Suppose that some blocks of exceptional quality had been reserved for columns, sarcophagi, or shrines. Apparently brought from a distant quarry, they might have been originally part of the temple-hill which still enclosed them.*

When, then, we find in the Sphinx, at the other end of the Nile valley, an equally simple and inexpensive piece of decorative engineering, one is naturally induced to enquire whether the enormous bulk of the pyramids above it is necessarily due to stones transported from the east bank of the Nile and raised to their present position. The three pyramids of Gizeh

Top of Second Pyramid	642.9
Top of Great Pyramid	612.10
Top of Third Pyramid	406.8
Top of Hill	250.0
Base of Third Pyramid	203.8
Base of Second Pyramid	195.3
Base of Great Pyramid	162.1
Head of Sphinx	80.0
Excavated Chamber	60.0
Sand plain at Base	33.8
High Nile of 1838	24.8
Low Nile of 1838	0.0

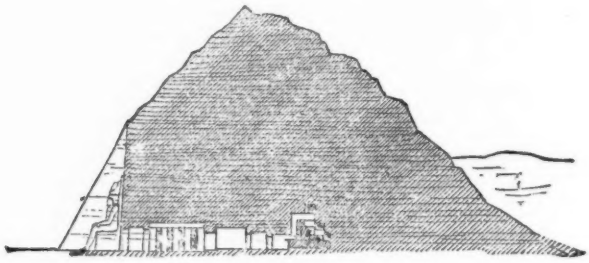


suggest the natural summits of a limestone hill. There is nothing artificial about the second and highest, except the triangular walls which revet its sides. The little pyramids seem to be only piles of rubbish. The top of the pyramid of Cheops is two hundred feet below the upper stratum of the cañon of the Nile. It is exactly the height of two natural hills about twenty miles to the west on the same parallel of latitude. It contains two chambers, a passage, and a few blocks of granite, but there is nothing to prove that these are not surrounded, as all other similar chambers and passages, by live rock. It is not a question of evidence but of belief. If you like to think that you are gazing upon the most stupendous and ineffectual exhibitions of human vanity, and that no other structures even furnish a scale with which to measure either the labor or the folly, there is no possible refutation of your opinion. If you prefer to believe that they are revetted hills, tradition aids this as well as the opposite view. It is also the stronger case. If this butte of Gizeh was like any other hill from Cairo to Khartoum, it must have had conical summits. After the quarrymen had honeycombed them, the engineers would have been compelled to take them down in part, and reconstruct them. Clouds of dust and falling stones would have impaired the use of the terrace below. It was indispensable to buttress these crumbling masses and fill their catacombs with rubbish. It was equally desirable to save them as great rocks in a weary land to shade the pools and temples. If this question were given to experts to be decided according to the strict rules of evidence, the decision would be in favor of those who hold that like Ipsambool and Petra these mounds were constructed with gravity and not against it. No importance appears to have attached to

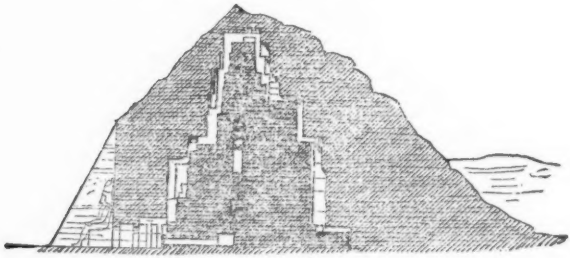
* The fame of the *trilithon* of Baalbek is largely due to a misconception. The immense stones sixty feet in length were quarried on the spot, above their present site. The word is not Greek but Arabic. It does not mean *three stones*, but refers to the Litany, at whose source this fortress stands. The so-called "fourth stone" is simply a partly quarried mass of much more recent date.

them in popular estimation. The peasants told Herodotus that they were constructed from above by the same iconoclastic Philistines who carved the hills at Amrit into country houses. The Copts told ibn-Wasyf that they were worked down from the top. It is the easier method and the more pleasant alternative. The engineer would mark out a rectangle with care. Then the stones, detached from the upper part of the hill, would be quickly moved to the nearest spot. The bearing surfaces would require to be dressed with some pains, but the perpendicular joints might be neglected.

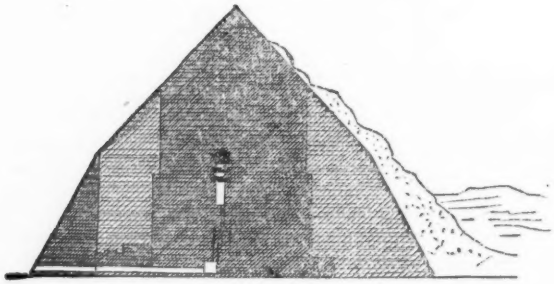
Positive evidence in favor of this theory is offered by a careful inspection of the middle courses of the pyramid of Cheops. Some of the stones show traces of geological waste. If a large part of the material was quarried at a considerable distance, where did the workmen pick up such blocks as these? They are evidently fragments of exposed strata. They are literally crust; baked by the



SECTION OF THE SPEOS OF ABU-SIMBEL.

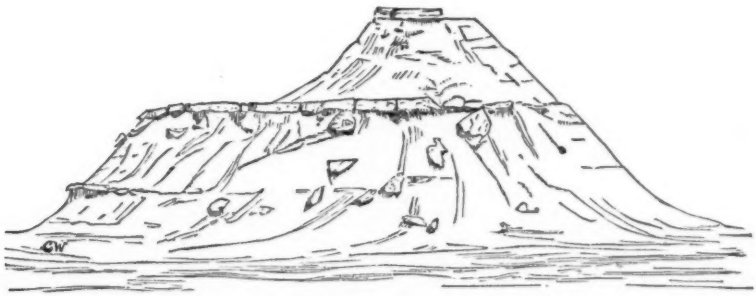


THE TEMPLE DESTROYED BY OVERSTOPING.



THE PYRAMID COMPLETED "FROM ABOVE."

sun, worn by the sand, eroded by the Nile in prehistoric ages. There is no wear and tear in their present site. Mere scratches made by tourists of the Christian era are still legible. Besides, there is a tradition of Herodotus that in building these pyramids, temples were destroyed. There would be only one way to destroy Ipsambool. A rock-hewn temple is as imperishable as it is cheap. But it is always possible to fill up the temple from above, until the hill has been rebuilt downwards. The engineer could overstope to the summit, and every vestige of the shrine would disappear. If he then revetted it from above, the high-place would lose every distinctive feature. By such a method alone could the crust of the hill be the outside of the pyramid. If this is so, the pyramid



PYRAMIDAL HILL IN THE DESERT. Long. 30° 55′. Lat. 29° 30′.

did not grow by concentric coatings like the bark of a tree, nor by horizontal layers diminishing in size. A space in the center of the natural mass was carried by passages and chambers through the whole elevation. The interior would be rebuilt, and the natural pillars strengthened. "The top was finished first," said Herodotus, "then the middle parts, and lastly, those that were on the ground." The engineer had the satisfaction of knowing that enduring work had been accomplished at little cost. The Government was so well satisfied with the prodigious equivalent for the million and a half of dollars, which it had expended, that it inscribed the cost so that posterity might audit the accounts of its stewardship. Did the elector of Hesse dare to engrave on Wilhelmshöhe the price his subjects paid for the forms but not the virtues of antiquity? Did even Pericles care to put on the walls of the Parthenon the nominal outlay for the temple which served as a pretext for plundering the military chest of the allies. When a handful of men justified the distinction made by Aristotle between the government of the best, who are necessarily few, and the government of the basest, who are accidentally whirled into power, did they record upon the successive stages of the Court House the successive issues of county bonds? Will the Archbishop of Paris write upon the water table of Notre Dame de Montmartre, that before the first stone was visible on that ill-chosen site more money had been expended than when the summit of the second pyramid rose completed six hundred feet above the altar of the Sphinx? Yet these pyramid-builders, of whom the Egyptians said, "kings reign, engineers govern," have been a by-word and reproach for centuries. But converse with the mighty dead by their great canals, and lamentation over the sepulchres of their sand-strewn reservoirs, give courage to utter a word in their defence. Should Lake Mœris be restored in my lifetime, I will surely build another pyramid to the memory of these engineers. I will take the hill which lies to the north of the Fayoum and reconstruct it within and without. Upon it I will cut, as they did, the cost of the work in terms of several standard articles of food, and leave this monument on the frontier of human thought as an eternal evidence at what a price one may do his work too wisely and too well.

THE GENERAL THEORY OF THERMO-DYNAMICS.

By Professor OSBORNE REYNOLDS, F.R.S.*

From Papers of the Institution of Civil Engineers.

In lecturing on any subject, it seems to be a natural course to begin with a clear explanation of the nature, purpose, and scope of the subject. But in answer to the question—What is thermo-dynamics? I feel tempted to reply—It is a very difficult subject, nearly, if not quite, unfit for a lecture. The reasoning involved is such as can only be expressed in mathematical language. But this alone should not preclude the discussion of the leading features in popular language. The physical theories of astronomy, light, and sound involve even more complex reasoning, and yet these have been rendered popular, to the very great improvement of the theories. Had it appeared to me that it was the necessity for mathematical expression which alone stood in the way of a general comprehension of this subject, I should have felt compelled to decline to deliver this lecture, honorable as I acknowledge the task to be.

What I conceive is the real difficulty in the apprehension of the leading features of thermo-dynamics is, that it deals with a thing or entity (if I may so call heat) which, although we can recognize and measure its effects, is yet of such a nature that we cannot with any of our senses perceive its mode of operation.

Imagine, for a moment, that clocks had been the work of Nature, and that the mechanism had been on such a small scale as to be imperceptible even with the highest microscope. The task of Galileo would then have been reversed; instead of inventing machinery to perform a certain object, his task would have been from the observed motion of the hands to have discovered the mechanical principles and actions of which these motions were the result. Such an effort of reason would be strictly parallel to that which was required for the discovery of the mechanical principles and actions of which the phenomena of heat were the result.

In the imaginary case of the clock, the discovery might have been made in either of two ways. The scientific method would have been to have observed that the motion of the hands of the clock depended on uniform intermittent motion; this would have led to the principle of the uniformity of the period of vibrating bodies, and on this principle the whole theory of dynamics might have been founded. Such a theory would have been as obscure, but not more obscure, than the theory of thermo-dynamics. But there was another method in the case of timekeepers, the one by which the theory of dynamics was actually brought to light—namely, the invention of an artificial clock, the action of which could be seen, and, so to speak, understood. It was from the pendulum that the constancy of the periods of vibrating bodies was discovered, and from this followed the dynamical theories of astronomy, light, and sound. There is no great difficulty in the apprehension of these theories, because they do not call for the creation of a mental picture, but merely for the exaggeration or diminution of what we can actually see in the clock.

As regards the mechanical theory of heat, however, no visible mechanical contrivance was discovered or recognized which afforded an example of this action; apparently, therefore, the only possible method was the scientific method—namely, the discovery of the laws of its action from the observation of the phenomena of heat, and accepting these laws, without forming any mental image of the dynamical origin, was the only method open. This is what the present theory of thermo-dynamics purports to be.

But although the theory of thermo-dynamics may be said to have been discovered in the form in which it is now put forward, this is not quite true. For one of the discoverers of the second law, and the one who had priority over the others, worked by the aid of a definite mechanical hypothesis as to the actual molecular motions and forces on which the phenomena of heat depend, and many of the most important steps in the theory are

* The lecturer was elected M. Inst. C.E. on the 4th of December following.

solely to be attributed to his labors. But to return to the theory. This may be defined as including all the reasoning based on two perfectly general experimental laws, without any hypothesis as to the mechanical origin of heat. In this form thermo-dynamics is a purely mathematical subject and unfit for a lecture. But as no one who has studied the subject doubts for a moment the mechanical origin of these laws, I shall be following the spirit, if not the letter of my subject, if I introduce a conception of the mechanical actions from which these laws spring. And this I shall do, although I should hardly have ventured, had it not been that, while considering this lecture, I hit on certain mechanical contrivances which afford sensible examples of the action of heat, in the same way as the pendulum is an example of the same principles as those involved in the phenomena of sound and light. These examples, thanks to the ready aid of Mr. Forster in constructing the apparatus, I am in a position to show you, and I am not without hope that these kinetic engines may in a great measure remove the source of obscurity on which I have dwelt.

The general action of heat to cause matter to expand, or to tend to expand, is sufficiently obvious and popular. That the expanding matter will do work is also sufficiently obvious, but the exact part which the heat plays in doing this work is very obscure.

It is now known that heat performs two, and it may well be said three, distinct parts in doing the work. These are—

(1) To supply the energy equivalent to the work done.

(2) To give the matter the elasticity which enables it to expand, *i.e.*, to convert the inert matter into an acting machine.

(3) To convey itself (*i.e.*, heat) in and out of the matter.

This third function is generally taken for granted in the theory of thermo-dynamics.

In order to make any use of thermo-dynamics, a knowledge of the experimental phenomena of heat is necessary; but as time will not permit of my entering largely into these, I have had some of the leading facts suspended as diagrams. One or two it will be well to mention.

Heat as a quantity is independent of temperature, the thermal unit taken being the amount of heat necessary to raise 1 lb. of matter 1° Fahrenheit.

Temperature represents the intensity of heat in matter. Matter in most of its forms expands more or less uniformly as we add heat to it; hence the expansion of matter measures temperature. Gases such as air expand in absolute proportion to the heat added under a constant pressure.

Absolute temperature is an idea derived from the observed rate of contraction of gases; they would vanish to nothing with the temperature 461° below zero Fahrenheit. For the other phenomena I must refer to the diagrams as I proceed.

Our knowledge of these facts has been accumulating during the last two hundred years, and it was in a very complete condition forty years ago, before thermo-dynamics was born. The birth of this science may be considered as the result of the recognition of work—motion against resistance as a true measure of mechanical action, and of accumulated work or energy as the potency of all sources of power. These ideas have now become extremely popular, and all are able to recognize in the raised weight, the bent spring, the moving hammer, the same thing, energy, which is measured by the amount of work which can be derived from any of these sources.

Before the recognition of this means of measuring mechanical potency, any definite idea of the true mechanical action of heat was impossible, for we had not recognized the only mechanical action by which it can be measured.

In 1843 Joule conclusively proved that, by the expenditure of 772 ft.-lbs. a thermal unit of heat must be produced, provided all the work was spent in producing heat. The simplicity of the ideas here involved, and the completeness of Joule's proof, acted at once to render the first law popular. No language can be too strong in which to express the importance of this discovery; yet, as was long ago pointed out by Rankine, the very popularity of Joule's law went a long way to obscure the fact that it did not constitute the sole foundation of the theory of ther-

mo-dynamics. Before Joule's discovery it was recognized that heat acted a part in causing work to be performed. It was clearly seen that it was heat which caused the water to expand into steam, against the resistance of the engine, and the necessity of heat to cause matter to expand was recognized.

To make matter do work, it was only necessary to heat it. It would expand, raising a weight; and since after doing its work the matter was still hot, it was supposed that the only necessity for the heat was to add increased elasticity to matter. It was seen that the heat that had once been used was so degraded in temperature that it could not be all used again. So that, although there was no idea that heat was actually consumed in doing the work, it was seen that for continuous work a continuous supply of heat at a high temperature was necessary. As regards the exact proportion of heat required for the supply of elasticity, to perform a certain quantity of work, fairly clear ideas prevailed. It was seen that this depended on various circumstances. These were formulated by Carnot, who in 1828 gave a formula, which is equivalent to our second law of thermo-dynamics, of which it was the parent.

Now this idea that heat merely caused work to be done was not absurd, as is sometimes supposed. Indeed we may say that the present popular idea that the whole heat is convertible into work is more erroneous than the old idea in the ratio of 10 to 1; because the old idea that the function of heat is to supply elasticity was right, as far as it went. Although the present idea that the function of heat is to supply energy from which the work is drawn is also right; yet, in any known possible heat-engine ten times more heat is necessary for the purpose of giving elasticity to matter than is converted into work by elasticity. This error, which seems to be very general amongst those who have not made a special study of the subject, may, I think, be attributed—first, to the popularity of the first law of thermo-dynamics, and secondly to the fact that although the second law of thermo-dynamics is nothing more nor less than a statement of the proportion which the quantity of heat necessary to produce elasticity bears to the quantity which this elasticity will convert into work, yet that it is the invariable custom in stating this law to omit all attempt to explain the purpose which this excess of heat serves; the reason for this omission being that experiment only shows that this heat is necessary, and hence this is all that we have a right to say.

If such an error prevails it is only a popular error, for it certainly did not affect the progress of the science. No sooner did Joule's law become known than it was taken up by Rankine, who, in 1849, published a complete theory of thermo-dynamics, based, as I have said, on a hypothetical constitution of matter. This was almost simultaneously followed by theories based on an improved form of Carnot's reasoning by Thomson and Clausius.

Rankine's theory was based on a hypothetical constitution of matter. He invented a system of molecular motions and constraints, which he called molecular vortices, and he then calculated the effects of these motions by the theory of mechanics. The fact that his reasoning was based on a hypothesis was considered by many as a fault in his reasoning. But on the other hand the clear idea thus obtained, as to the reason of everything he was doing, gave him such an advantage over those who were working by experimental laws, of the meaning of which they would venture no opinion, that he was led to make discovery after discovery in advance of his competitors, while some of his discoveries are still beyond the reach of experiment.

There was, however, a difficulty Rankine had to face; some properties of matter were pointed out which his hypothetical matter did not possess. This was not much to be wondered at, for although Rankine had invented machinery which would account for the mechanical action of heat, there was no reason to suppose this to be the only machinery. Rankine, with a view to the difficult calculations he had to make, had chosen machinery as simple as possible. Instead, however, of trying to complicate it, he, yielding to the opinion of his contemporaries, adopted the general conclusions to which it had led him as axiomatic laws, and so cut himself adrift from his hypothesis.

It comes to be, then, that the student of thermo-dynamics finds as a reason why we must pass a large amount of

heat through his engine, besides that which is converted into work, he is to accept an axiomatic law as to the greatest possible amount that can be converted under the circumstances.

To tell a child who asks why he cannot have more food, that he can only have 6 oz. a day, would be considered cruel. So, to tell a student who wants to know why, out of the ten million foot-lbs. in 1 lb. of coal, a steam engine can only give one million as work, that he is only allowed $\frac{T_1-T_2}{T_1+461}$, is cruel, yet this is all he can have from the theory of thermo-dynamics based on its experimental laws.

Rankine, when compelled to abandon his hypothesis as the foundation of his theory by the objections justly urged against it, pointed out the great disadvantage of a mechanical theory conveying no conception of the mechanical basis of its laws; and called on all those who taught the subject to try and find some popular means of illustrating the second law.

This call was made twenty years ago, but, I believe, up to the present time no such illustration has been forthcoming. When undertaking this lecture I had no idea of such an illustration, and I did not intend to say much as to the reason of the second law. But, as I have said, three weeks ago an idea occurred to me. It arose in this way: Heat acts in matter to transform heat into work by molecular mechanism. Having much studied the subject, I have in my mind a picture, right or wrong, of the mechanism, and the part which heat acts. The question occurred—Is there no way of making a machine such that, although the parts are in visible motion, and the energy transformed to work is visible energy, yet the energy supplied shall have the characteristics of heat energy, and the machine shall act simply in virtue of the elasticity caused by the motion of its parts?

The question had no sooner arisen than several ways of carrying out the idea presented themselves.

The general idea of the mechanical condition which we call heat is, that the particles of matter are in active motion; but it is the motion of the individuals in a mob, with no common direction or aim. Rankine assumed the motion to be rotatory, but it now appears more probable that the motion in the particles is oscillatory, undulatory, rotatory, and all kinds of motion whatsoever; so that the communication of heat to matter means the communication of internal agitation —mob agitation. If, then, we are to make a machine to act the part of hot matter, we must make a machine to perform its work in virtue of the communication of internal promiscuous motion amongst its parts. The action of heat-mechanism to do work is simply that of expansion of volume, or the increased effort to expand owing to increased agitation. I first tried to think of some working arrangements of small bodies which should forcibly expand when shaken; but it appeared that it would be much easier to effect a contraction. This was as good. As long as any definite alteration in shape could be produced against resistances by a definite amount of agitation in its parts, we should have a machine illustrating the action of the heat engine.

Suppose we want to raise a bucket from a well. Our best way is to pull or wind up the rope, but that is because the energy we employ is in a completely directable form. Suppose we had no such directable energy, but could only shake the rope, it having been first made fast at the top (Fig. 1). Then, it being a heavy rope, a chain is better; suppose we shake the chain laterally, waves will run down the chain, and, if we go on shaking, the chain will assume a continuously-changing sinuous form (Figs. 2 and 3); and, as the chain does not stretch, the bucket must be raised for the sinuosities. The chain will have changed its mechanical character, and from being a tight line or tie in a vertical direction, will possess kinetic elasticity, that is, elasticity in virtue of its motion, causing it to contract its vertical length.

The bucket will be raised, although not to the top of the well, and work will have been done in raising it, but the work spent in shaking the chain will be not only the equivalent of the work spent in raising the bucket, but also of all the kinetic agitation in the chain necessary to raise the bucket. Having raised the bucket as far as possible with a certain power of agitation, if the supply of

agitation be cut off, then that already in the chain will sustain the bucket until it is destroyed by friction, when the bucket will gradually descend.

But, if we want to do more work, to raise another bucket, we may take that which is raised off at the level at which it is raised; then, to get the chain down again, we must allow it to cool, *i. e.*, allow the agitation to die out; then, attaching another bucket, to raise this we shall again have to supply the same heat, perform the same work, *i. e.*, the work to raise the bucket, and the agitation energy of the chain. Thus we see that the energy necessary to the working of the machine serves two purposes, it supplies the energy necessary to raise the bucket, and the energy necessary to convert the chain from an inextensible tie into an elastic contracting system, capable of raising the weight, neither of which portions of energy is again serviceable after the bucket has been raised. The one portion is already converted into work, and the other, although still in existence in the chain as energy, can only sustain the position of the chain. Before it could be used to do more work it must be got out of the chain and back again, which is just the thing you cannot do; we can get some of it out and some of it back, but not all.

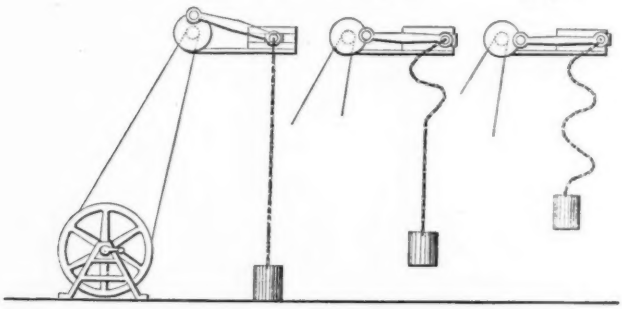
It must not be supposed that this method of raising a bucket by shaking the rope is recommended as the best means. No one would dream of using it if we could get a direct pull, but that is nothing to the point. We are considering the action of heat, and we have limited ourselves to using energy of the same kind that heat supplies; that is, energy in the form of promiscuous agitation, absolutely without direction, so that the question is, how can we raise the bucket by shaking?

I feel that there is a childish simplicity about this illustration that may at first raise the feeling of "Abana and Pharpar, rivers of Damascus," in the minds of some of my hearers; but, should this be the case, I have every confidence that calm reflection will have the same effect as on Naaman.

The case of the shaken rope, as I have put it, is no mere illustration of the action of heat, but an instance of the same application of the same principles. The sensible energy in the shaking rope only differs from the energy of heat, *i. e.*, a bar of metal is the scale of the motion; we see that in the chain, but not in the bar, not because the molecules of the bar are moving slower, but because the scale of motion is infinitely smaller. The temperature of the bar, from absolute zero, measures the mean square of the velocity of all its parts, multiplied by some constant depending on the mass of the parts which are moving together; so the mean square of the velocity of the chain, multiplied by the weight per foot of the chain, really represents the absolute temperature of the sensible energy in the chain.

The apparatus which I have on the table is an obvious adaptation of the rope and the bucket. There are three different illustrations apparently very different

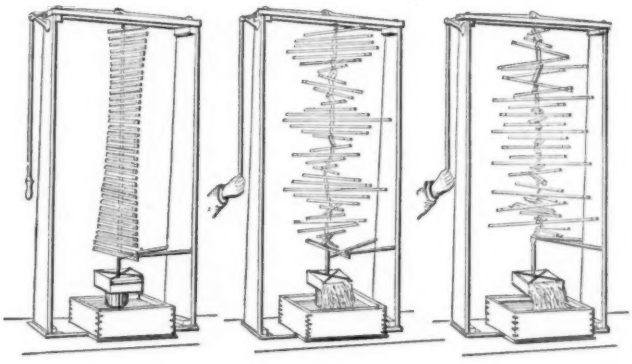
Fig. 1 Fig. 2 Fig. 3



in form, but all working by the same principle.

Here is the chain (Figs. 1, 2, 3), by the shaking of which (addition of promiscuous energy) a weight of 2 lbs. is raised 3 feet, or 6 foot-lbs. of work done; here is another sort of chain, a series of parallel horizontal bars of wood, connected and suspended by two strings (Figs. 4, 5 and 6). By giving a circular oscillation to the upper bar, the whole apparatus is set into a twisting motion (agitation); the strings are continually bent, and the vertical length of the whole system is shortened, and a weight of 10 lbs., or the bucket of the pump, is caused to rise, raising water just as if we boiled water under the piston of a steam engine. To get the buck-

Fig. 4 Fig. 5 Fig. 6



et down again for another stroke, we must quiet or cool the chain, just as we must condense the steam, and the energy taken out of the chain in cooling corresponds exactly with the heat that must be taken out of the steam in order to condense it.

The waves of the sea constitute a source of energy in the form of sensible agitation; but this energy cannot be used to work continuously one of these kinetic machines, for exactly the same reason as the heat in the bodies at the mean temperature of the earth's surface cannot be used to work heat engines. A chain attached to a ship's mast in a rough sea would become elastic with agitation, but this elasticity could not be used to raise cargo out of the hold, because it would be a constant quantity as long as the roughness of the sea lasted.

In practical mechanics we have no source of energy consisting of sensible agitation, besides the waves of the sea; so that there has been no demand for these kinetic engines to transform sensible mob energy into work; had there been, I might have patented my idea, though probably it would have long ago been discovered. But there has been a demand for what we may call sensible kinetic elasticity, to perform for sensible motion the part which the heat elasticity performs in the thermometer, and for this purpose the principle of the kinetic machine was long ago applied by Watt. The common governor of a steam engine acts by kinetic elasticity, which elasticity depending on the speed at which the governor is driven, enables the governor to contract as the speed increases. The motion of the governor is not of the form of promiscuous agitation, but, though systematic, all the motion is at right angles to the direction of operation, so that the principle of its action is the same.

The kinetic elasticity of the governor performs the same part as the heat elasticity in the matter of the thermometer; the first measures by contraction the velocity of the engine, and the other measures by expansion the velocity of the molecules of the matter by which it is surrounded, so that while we now see that while measuring the speed of sensible revolution, we are performing on a

different scale the same operation as measuring the temperature of bodies, which depends on the molecular velocities, and that quite unconsciously we have constructed instruments to perform the two similar operations which act by means of the same mechanical action, namely, kinetic elasticity.

These kinetic examples of the action of heat must not be expected to simplify the theory, except in so far as they give the mind something definite to grasp; what they do is to substitute something we can see for what we can barely conceive.

The theory of thermo-dynamics can be deduced from any one of these kinetic examples by the application of the principles of mechanics; such application involves complex dynamical reasoning, such as can only be executed by the aid of mathematics, and would be altogether unfit to introduce into a lecture. I shall therefore pass on to some considerations resulting from the theory of thermo-dynamics.

The discovery of the two laws have enabled us to perfect and complete our experimental knowledge of the phenomena of heat. But probably the greatest practical use is that these two laws enable us to calculate with certainty, from the experimental properties of any matter, the extreme potency of any source of power.

Thus we find by experiment that a pound of coal burnt in a furnace yields fourteen to sixteen thousand thermal units of heat. The first law, Joule's law, tells us at once that this is equivalent to from 11,000,000 to 13,000,000 foot-lbs. of energy. But this is not, as seems to be generally supposed, the power of coal. The second law of thermo-dynamics tells us that in order that this energy might be realized, it must be capable of being developed at an infinite temperature, whereas we know that this cannot be the case; and there is a growing idea that the temperature at which coal will burn is not so extremely high, about 3,000° Fahrenheit. Taking this temperature, and assuming the temperature of the atmosphere to be 60°, we have for the proportion of the heat of coal, that we could with a perfect engine call power, $\frac{2940}{3461}$, about 80 per cent., or from 9,000,000 to 11,000,000 foot-lbs.

Again, we know the heat properties of all known liquids and gases, so that we can, by the second law, tell the greatest possible proportion of the heat received, which can be converted into power by any of these agents.

In the steam-engine, for instance, we see that the present limits of art restrict the temperatures absolutely to 400°, and practically the limits are much less; while the lowest temperature that can be worked to in a condenser is 100°. Then, as the limit to the possibility, we have one-third as the greatest proportion, or three out of the nine million foot-lbs.

The greatest actual achievement by Mr. Perkins has been about two millions, while the best engines in use only give us a little over one million, or about one-ninth of the possible realizable portion between 3,000° and the mean temperature of the earth's surface.

I cannot here enter upon these, but the reasons why higher temperatures cannot be used in the steam-engine are obvious enough.

The same reasons do not apply to hot air as an agent. This may be worked at much greater temperatures; and about thirty years ago, as soon as it appeared from the science of thermo-dynamics that the limit of efficiency depended on the range of temperature, attention was much directed to air as a substitute for steam. The attempts then made failed through what were then called practical, or art difficulties.

Just at the present time the possibility of other heat-engines than steam-engines is again come to the front; and as this is so, it seems desirable to call attention to a circumstance connected with heat-engines which has as yet occupied quite a subordinate place in the theory of heat-engines. This is the law as to the rate at which heat can be made to do work by an agent, such as steam or air. The greatest possible efficiency of the agent, *i.e.*, the proportion which the work done bears to the mechanical equivalent of the heat spent, is a matter of fundamental importance; but the rapidity with which the heat can be so transformed with a given amount of apparatus, as an engine of a given weight, is a matter of at least as great importance.

Which would be the best engine for a steamboat; one that would develop 20 HP. for every ton gross weight, consuming 2 lbs. of coal per HP. per hour, or

one that only gave 2 HP. per ton weight, and only consumed 1 lb. of coal? Unquestionably the former; yet hitherto the question of heat economy has been considered theoretically, to the exclusion of time economy. Yet the latter forms a legitimate part of the subject of thermo-dynamics, and has played a greater part in the selection of steam as the fittest agent than the consideration of the heat-economy.

In the theory of thermo-dynamics it is assumed that the working agent, be it water or any other, can be heated up and cooled down at pleasure, without any consideration as to the time taken for these operations, which are considered to be mere mechanical details.

Yet in the science of heat a great amount of labor has been spent; a great amount of knowledge gained as to the rate at which heat will traverse matter. And more than this; it is well known that heat cannot be made to enter and leave matter without a certain loss of power, *i.e.*, a certain lowering of the working range of temperature. It is by heat that heat is carried into the substance; and hence, as I have indicated, there is a third law of thermo-dynamics relative to this transmission. Heat only flows down the gradient of temperature, and in any particular substance the rate at which heat flows is proportional to the gradient of temperature. Hence to get the heat from the source or furnace into the working substance a certain time must be consumed, and this time diminishes as the difference of temperature of the furnace and the working substance increases.

The examples of the kinetic engines which I have shown you will illustrate this. If we shake the end of a chain, the wriggle passes along the chain at a given speed. It appears that an interval must elapse between the first shaking of the chain and the establishment of sufficient agitation to move the bucket; a further interval before the bucket is completely raised; and further still, another interval must elapse before the chain can be cooled again for another stroke; so that this kinetic engine will only work at a given rate. I can increase this rate by shaking harder, but then I expend more energy in proportion to the work done.

This exactly corresponds with what goes on in the steam-engine, only, owing to the agent—water—being heated, expanded, and cooled severally in the boiler, cylinder, and condenser, the connection is somewhat confused.

But it is clear that for every HP. something like 15 million foot-pounds of power have to pass from the furnace into the boiler. As out of this 15 we cannot use more than two million, the remaining 13 are available for forcing the heat from the products of combustion into the water, and out of the steam into the condensing water, and they are usefully employed for this purpose.

The boilers are made small enough to produce sufficient steam, and this size is determined by the difference of the internal temperature of the gases in the furnace and the water in the boiler, and whatever diminishes this difference would necessarily increase the size of the heating surface, *i.e.*, the weight of the engine. The power which this difference of temperature represents cannot be realized in the steam-engine, so that it is most usefully employed in diminishing the necessary size of the boiler. Still it is an important fact to recognize that our present steam-engines require the expenditure of more than five times as much of the power of the heat (not of the heat) in getting the heat into the working substance as in performing the actual operation. This loss of power does not so much occur in the resistance of the metal which separates the furnace from the water as in the resistance of the gases. Gas is a very bad conductor; and though a thin layer adjacent to the plates is always considerably cooled, little further cooling goes on until, by the internal currents, this layer is removed, and a fresh hot layer substituted in its place.

Similar resistance would occur inside the boiler between the water and the hot plate, nay does occur, until the water begins to boil, but then the evaporation of the water takes place at the hot surface, and every particle of water boiled absorbs a great deal of heat, which leaves the surface in the form of bubbles, allowing fresh water to come up.

If we had air inside the boiler instead of water, we should require from five to ten times the surface to carry off the same heat, which is a sufficient reason why what are called hot-air engines can-

not answer, even did not the same argument hold with enormously greater force in the condenser.

Steam is as bad a conductor of heat as air as long as it does not condense, but, in condensing, steam will conduct heat to a cold surface at an almost infinite rate, for as the steam comes up to the surface it is virtually annihilated, leaving room for fresh steam to follow, which it will do if necessary with the velocity of sound. If, however, there is the least incondensable air in the steam this will be left as a layer against the fresh steam. Some years ago I made some experiments on this subject, which showed that 5 or 10 per cent. of air in the steam would virtually prevent condensation.

If a flask be boiled till all the air is out, and nothing but pure steam is left, and if the flask be then closed and a few drops of cold water introduced, the pressure instantly falls to zero, though it immediately recovers from the boiling of the water in the flask. If now a little air be admitted, and allowed to mix with the steam, the few drops of water produce scarcely any effect.

The facility with which steam carries heat to a cold surface is both an enormous advantage and some drawback; as compared with air it is an enormous advantage in enabling the steam to be cooled in the condenser. But during the working of the steam in the cylinder, when the steam is wanted to keep its heat, the facility with which it condenses is a great drawback, and necessitates the keeping of the cylinder hotter than the steam by a steam-jacket. For this part of its work the non-conductivity of incondensable air is a great advantage.

In dwelling thus on the conducting powers of air and steam, my purpose has been to prepare the way for a few remarks I wish to make on another form of heat-engine—the engine in which the heat is generated in the working substance itself.

The combustion engine, in the form of the cannon, is the oldest form of heat-engine. Here the chemically separate elements in the form of gunpowder are the working substances put into the cylinder; they take in with them the potential energy of chemical separation, which by means of a spark take the kinetic form of heat. Here there is no conduction, the kinetic elasticity propels the shot, and all the heat over and above that used in imparting energy to the shot is lost. The advantages of this form of engine are two. There is no time necessary for conduction, and as the gas generated is not condensable, there is little loss of heat by conduction to the cold metal.

These two advantages are very great, but I should not have mentioned them in reference to guns were it not that there appears to be the dawning of an idea of taming this form of engine so as to substitute it for the steam-engine. To do this it is necessary to introduce coal or coal gas;—and oxygen in the form of air in place of gunpowder. The thermo-dynamic theory applied to such engines shows that they should possess great advantages over the steam-engine in point of economy. And the considerations I have brought forward as to the loss of the power of heat in the transference of heat from the furnace to the boiler seem to promise such engines an enormous advantage in rate of work, while the substitution of a non-condensable gas for steam in the cylinder seems to get over the art-difficulty of making cylinders to work under high temperatures. We cannot expect any piston to work in a cylinder of over 300° or 400° temperature, but with non-condensing gases the cylinder may be kept cool with little cooling effect on the gases contained in it, even if the temperature of these is 3,000°. This will be the case if the gas in the cylinder is not in a violent state of internal agitation, but it should be remembered that all internal currents much facilitate the conveyance of heat to the walls.

There is one drawback shown by the theory of these engines. The simple expansion of the gases resulting from combustion is not sufficient to cool them to anything like the temperature of 60°, and to get the greatest economy some of the remaining heat should be used to heat the fresh charge. To do this, however, would necessitate the extraction of the heat from one mass of gas to communicate it to another, which would introduce all the difficulties of the boiler increased by having gas instead of water.

But even wasting this heat, the theory still shows a large margin of economy for such engines over the present perform-

ance of steam-engines, a margin which is said to have been already realized in the gas engine, which is a form of combustion-engine in a high state of efficiency. Now, by means of Dowson gas, Messrs. Crossley seem to have obtained 2,000,000 out of the 10,000,000 ft.-lbs. in 1 lb. of coal. Further accomplishment in this direction is a question of art; but while on all other hands science shows impassable barriers not far in advance of the present achievements of art, in this direction thermo-dynamics extended to include the rate of operation shows no known barriers; while the fact that, as gas-engines, this system of combustion heat-engines has already established a footing assures them continual improvement.

In conclusion I would say, by way of caution, that the theory of thermo-dynamics does not lead to the conclusion, which seems to be generally held by those who have only realized the first law of the science, that the steam-engine is a semi-barbarous machine, wasting more than it uses, very well for those who know no science, but only waiting until those better educated have time to turn their attention to practical matters, and then to give place to something much better. Thermo-dynamics shows us not the faults but the perfections of the steam-engine in which there is no waste of power, since all is used either in doing work or in promoting the rate at which the work can be done. Next to the watch the steam-engine is the highest development of mechanical art, and the science of thermo-dynamics may be said to be the result of the study of the steam-engine.

On the motion of the president a cordial vote of thanks to Professor Reynolds was carried by acclamation, for his valuable contribution to a most important subject.

CUSHIONING IN ENGINES.

By GEO. L. MORTON, M. E.

Written for Van Nostrand's Engineering Magazine.

In order to avoid filling the entire clearance space of engine cylinders with live steam for each opening of the admission port, it is found advisable to resort to cushioning. This consists in closing the exhaust port before the return stroke is completed, so as to re-compress the enclosed spent steam, and by this means aid in filling the clearance space. The quantity of steam used is in this manner diminished by the amount thus compressed; but in accomplishing this reduction, the work required to re compress the residual steam is sacrificed. Thus one objectionable feature is obviated by introducing another one, which, in itself, is also objectionable. Evidently there is some point for each case beyond which this last detrimental effect will predominate over the good result following from it, or a point at which the benefits derived from cushioning are the greatest possible under the circumstances. With such adjustment it is apparent that we should be able to realize the greatest amount of work from a given quantity of steam that is attainable under the imposed conditions of pressure, proportion of clearance, and ratio of expansion; in other words, the amount of work realized from a unit volume of steam at constant pressure will be a maximum.

A means is thus afforded for finding the most advantageous point in the stroke for closing the exhaust port and commencing to cushion. An expression for the ratio of the work, divided by the volume of steam from which this work is derived, must first be found, and then, regarding the part of the stroke through which cushioning takes place as the independent variable, ascertain what value of this variable will make the above ratio a maximum. In the solution of this problem, which follows, it will be supposed that expansion and compression take place so that the pressure varies with reference to the volume in such manner that the product of these two factors is a constant—that is, the curves of expansion and compression will be regarded as hyperbolic. This is done, not

alone because it will render the equations of these curves more simple than they otherwise would be, but rather because ordinarily it is found that in practice the curves of the indicator card agree most nearly with the hyperbola. Theory alone would perhaps indicate a different curve, but practice has demonstrated that the hyperbola is the standard for the expansion of steam. In what follows, release will also be assumed to take place at the end of the stroke, but a means of making a correction for its earlier occurrence will be indicated.

Let Fig. 1 be an ideal indicator diagram, and let the following symbols denote the quantities pointed out in each case, viz.:

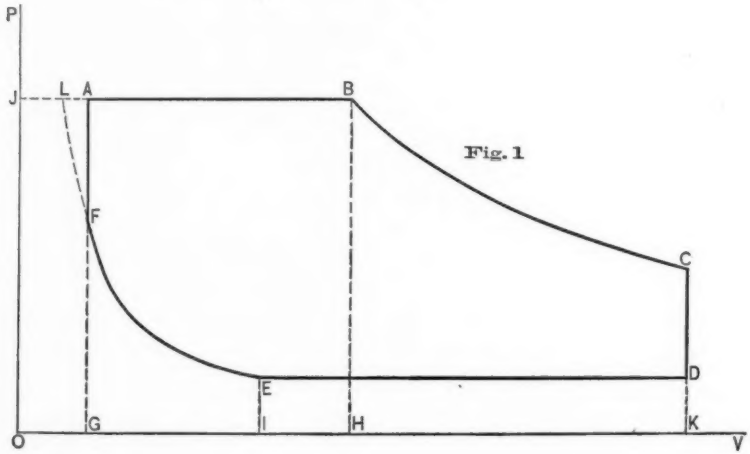


Fig. 1

v_1 = the volume of the clearance, as denoted by OG = JA in the diagram.

v_2 = the combined volume of the cylinder and clearance = OK.

p_1 = the initial absolute pressure = JO.

p_2 = the absolute back pressure during exhaust = DK.

p_3 = the absolute pressure to which steam is cushioned at the end of the stroke = FG.

v_4 = the volume of steam in the cylinder at the instant of closing the exhaust = OI.

c = the ratio of the combined volume of the cylinder and clearance at the instant of exhaust closure to the clearance volume $= \frac{v_4}{v_1}$.

v_3 = the volume of steam contained in the cylinder and clearance space at the instant of cut-off = JB.

r = the ratio of expansion $= \frac{v_2}{v_3}$.

For hyperbolic expansion the equation of the curve BC is, where p and r are respectively the pressure and volume at any point,

$$pv = p_1 v_3 = p_1 \frac{v_2}{r}; \qquad (1)$$

and the equation of the compression curve EF is, where p' and v' are respectively the pressure and volume at any point,

$$p'v' = p_2 v_4 = p_2 c v_1 \qquad (2)$$

From the foregoing conditions we may compute the amount of work realized as expressed by the area of the diagram. Let this area be denoted by A, then,

$$A = ABCDEF = ABHG + BCKH - EDKI - FEIG.$$

The area

$$ABHG = \left(v_3 - v_1\right)p_1 = \left(\frac{v_2}{r} - v_1\right)p_1;$$

$$BCKH = \int_{v_3}^{v_2} p\,dv = \int_{\frac{v_2}{r}}^{v_2} p_1 \frac{v_2}{r}\,\frac{dv}{v} =$$

$$\frac{p_1 v_2}{r} \text{ hyp. log. } r;$$

$$\text{EDKI}=(v_2-v_4)\,p_2=(v_2-cv_1)p_2;$$

and

$$\text{FEIG}=\int_{v_1}^{v_4} p'dv'=\int_{v_1}^{cv_1} p_2 cv_1\frac{dv'}{v'}$$
$$=p_2 cv_1 \text{ hyp. log. } c.$$

Hence

$$\text{A}=\left(\frac{v_2}{r}-v_1\right)p_1+\frac{p_1v_2}{r}\text{ hyp. log. } r$$
$$-(v_2-cv_1)\,p_2-p_2cv_1\text{ hyp. log. } c.$$

or

$$\text{A}=\frac{v_1p_2}{r}\left\{\left(\frac{v_2}{v_1}-r\right)\frac{p_1}{p_2}+\frac{v_2p_1}{v_1p_2}\text{ hyp. log. } r\right.$$
$$\left.-\left(\frac{v_2}{v_1}-c\right)r-cr\text{ hyp. log. } c.\right\} \quad (3)$$

If the volumes be expressed in cubic feet, and the pressures in pounds per square foot, then A represents the energy per stroke in foot-pounds.

In ascertaining the volume of steam used per stroke, it must be borne in mind that the steam due to cushioning in the previous stroke is retained in the cylinder. At the instant of exhaust closure this residual steam is under the exhaust pressure p_2, and it has the volume $v_4=cv_1$. If this steam be compressed until it sustains the pressure p_1, and if the law of compression be hyperbolic, it will have the volume

$$\text{JL}=\frac{cv_1p_2}{p_1}.$$

Let V′ equal the volume of steam used per stroke under the pressure p_1, then

$$\text{V}'=v_2-\frac{cv_1}{p_1}p_2=\frac{v_2}{r}-\frac{cv_1}{p_1}p_2. \quad (4)$$

The pressure p_1 will vary for different engines, and for the same engine at different times, so that, if the expression is to be perfectly general so as to serve as a ready means of comparison in all cases, this volume must be reduced to a standard pressure.

Let the standard pressure be represented by P, then let V be the volume under this pressure, and we have

$$\text{V}=\frac{\text{V}'}{\text{P}}=\frac{p_1}{\text{P}}\left(\frac{v_2}{r}-\frac{cv_1}{p_1}p_2\right) \quad (5)$$

This pressure is arbitrary, and it may be given any value. It will simplify the formula somewhat to make P equal to unity. Assigning P this value, and we have

$$\text{V}=\frac{v_1p_2}{r}\left\{\frac{v_2}{v_1}\frac{p_1}{p_2}-cr\right\}. \quad (6)$$

Let H equal the amount of work realized from a unit volume of steam at the pressure of unity, then

$$\text{H}=\frac{\text{A}}{\text{V}}=$$
$$\frac{\left(\frac{v_2}{v_1}-r\right)\frac{p_1}{p_2}+\frac{v_2}{v_1}\frac{p_1}{p_2}\text{hyp.log.}r-\left(\frac{v_2}{v_1}-c\right)r-cr\text{ hyp.log.}c}{\frac{v_2}{v_1}\frac{p_1}{p_2}-cr} \quad (7)$$

In employing this formula, since pressures and volumes appear as ratios, we may employ such units as are most convenient, provided both volumes be expressed in the same unit of volume, as cubic foot or cubic inch; and the two pressures in the same unit of pressure, as pounds per square inch or square foot.

Since we have the most efficient use of steam when the ratio H is the greatest possible, and having fixed upon the values that shall be given $\frac{v_2}{v_1}$, $\frac{p_1}{p_2}$, and r, let us find what value of c will, under these imposed conditions, make H a maximum. We shall thus be enabled to determine an expression for the proper point of exhaust closure. Taking the differential coefficient of H with respect to c, and placing it equal to zero, and we have, after reduction,

$$\frac{d\text{H}}{dc}=$$
$$\frac{r\left\{cr-\frac{p_1v_2}{p_2v_1}\text{hyp. log.}\frac{c}{r}+\left(\frac{v_2}{v_1}-r\right)\frac{p_1}{p_2}-r\frac{v_2}{v_1}\right\}}{\left(\frac{p_1}{p_2}\frac{v_2}{v_1}-cr\right)^2}=0;$$

whence,

$$cr-\frac{p_1v_2}{p_2v_1}\text{ hyp. log. } c=$$
$$\frac{v_2}{v_1}\left\{r-\frac{p_1}{p_2}(1+\text{ hyp. log.}r)\right\}+\frac{p_1}{p_2}r \quad (8)$$

This formula is the same as the one arrived at by Prof. Robinson in a paper on "Cushion Adjustment in Engines," published in the Transactions of the American Society of Mechanical Engineers. It is also substantially the same as the one given by Coterell in his work on "The Steam Engine." The equation

is an implicit function of c, and the value of c can only be obtained by a series of approximations which are too tedious to make the formula alone of much practical use. However, a table may be constructed by means of which, cases, that ordinarily occur in practice, may be readily solved. The task of constructing such a table is necessarily a laborious one. Prof. Robinson was the first to make a table of this kind. It was computed by means of a very ingenious method which reduced the labor to a large extent. However, this method was liable to slight inaccuracies. The table given below was computed by the more laborious, but it is thought more accurate method, of a direct numerical solution of the above equation for each particular case. This table, also, while in some respects more limited than that of Prof. Robinson, is, in others, susceptible of a wider application than the latter. In the first column on the left in Table I. is given the ratio of the steam pressure to the exhaust pressure for each case: in the second column are given the corresponding values of the ratio of the combined volume of the cylinder and clearance to the clearance volume. In the columns to the right of these are given the values of c for the above corresponding pressure and volume ratios, and for the ratio of expansion as given at the head of the column in each case.

In equation (8), if r be made equal to $\frac{p_1}{p_2}$, that is, if the expansion be carried to the exhaust pressure, then $c=r=\frac{p_1}{p_2}$.

Therefore, if the expansion be carried to the exhaust pressure, we should cushion to the initial pressure. This is the greatest possible value that c can have. Rankine's general statement that "the most advantageous adjustment of compression takes place when the quantity of steam confined is just sufficient to fill the clearance at the initial pressure," is true for only one particular case.

In practice it is desirable to know the point in the stroke where cushioning should begin, rather than the value of the ratio c. Having determined the value of c, the fractional part of the stroke through which the exhaust port remains open may be easily found. This fraction represents the part of the return stroke passed through before cushioning begins. The volume of the cylinder displacement at the point of exhaust closure $=v_2-v_1c$, and the cylinder volume proper $=v_2-v_1$; therefore, if we let M denote the fraction of the stroke passed through by the piston up to the point of exhaust closure, we have

$$M=\frac{v_2-cv_1}{v_2-v_1}=\frac{\frac{v_2}{v_1}-c}{\frac{v_2}{v_1}-1} \qquad (9)$$

By means of this formula and the table of values for c, the following table was computed giving the corresponding values of M. It is evident that $1-M$ equals the part of the stroke through which cushioning takes place. Table II. is similar in form to Table I., the value of M being given in the body of the table in place of c.

For cases intermediate between those given in the above table, sufficiently accurate results may be obtained by means of interpolation. The equation and tables already given may be applied to all ordinary steam and air engines. If, from any cause, as "wire drawing" at the point of cut-off, early release, or a more rapid fall of pressure in expansion than the hyperbolic law supposes, it is found impracticable to realize the amount of work from a given volume of steam that we have supposed in our theoretical diagram, cushioning should be made to begin slightly later than the table would indicate. While if, from any cause, the amount of energy derived be greater than that heretofore supposed, the point of exhaust closure should be slightly earlier. Or, in more general terms, any cause that increases the ratio of work divided by volume hastens the exhaust closure, while any cause that diminishes this ratio retards it.

Equation (7) affords a convenient means for comparing the efficiency of steam used under various conditions.

Thus, suppose an engine in which $\frac{v_2}{v_1}=30$, $\frac{p_1}{p_2}=6$, and $r=4$, then, by the first table it will be found that for the most advantageous cushion point $c=5.53$; substituting these values in equation (7), and

TABLE I.

Giving the ratio, c, of the maximum pressure due to cushioning to the exhaust pressure.

$\frac{p_1}{p_2}$	$\frac{v_2}{v_1}$	Value of c for the following values of the ratio of expansion.					
		$r=1.$	$r=\frac{3}{2}.$	$r=2.$	$r=4.$	$r=6.$	$r=8.$
4	10	2.02	2.66	3.16	4.00		
4	20	2.07	2.74	3.24	4.00		
4	30	2.08	2.76	3.26	4.00		
4	40	2.09	2.77	3.27	4.00		
6	10	2.16	2.94	3.59	5.34	6.00	
6	20	2.23	3.06	3.75	5.49	6.00	
6	30	2.26	3.10	3.80	5.53	6.00	
6	40	2.27	3.12	3.82	5.54	6.00	
8	10	2.23	3.08	3.82	5.96	7.32	8.00
8	20	2.32	3.23	4.03	6.32	7.59	8.00
8	30	2.35	3.28	4.10	6.42	7.63	8.00
8	40	2.36	3.33	4.12	6.47	7.67	8.00
10	10	2.28	3.17	3.94	6.28	7.88	9.04
10	20	2.36	3.34	4.20	6.86	8.67	9.63
10	30	2.40	3.40	4.30	7.00	8.72	9.69
10	40	2.42	4.43	4.33	7.05	8.76	9.72
14	10	2.33	3.27	4.09	6.62	8.34	9.53
14	20	2.43	3.46	4.40	7.44	9.69	11.40
14	30	2.47	3.53	4.51	7.70	10.05	11.77
14	40	2.48	3.56	4.56	7.82	10.19	11.92

TABLE II.

Giving the fraction of the stroke passed through by the piston up to the point of exhaust closure for maximum efficiency.

$\frac{p_1}{p_2}$	$\frac{v_2}{v_1}$	Fraction of Stroke for the following values of r.					
		$r=1.$	$r=\frac{3}{2}.$	$r=2.$	$r=4.$	$r=6.$	$r=8.$
4	10	.887	.827	.760	.667		
4	20	.944	.909	.884	.842		
4	30	.963	.939	.922	.895		
4	40	.972	.955	.942	.923		
6	10	.871	.785	.712	.518	.444	
6	20	.935	.892	.856	.764	.737	
6	30	.957	.924	.903	.844	.828	
6	40	.967	.946	.928	.883	.872	
8	10	.863	.769	.687	.449	.298	.222
8	20	.931	.883	.841	.720	.653	.632
8	30	.954	.922	.893	813	.772	.759
8	40	.969	.944	.902	.859	.829	.821
10	10	.858	.759	.673	.413	.236	.107
10	20	.849	.877	.832	.692	.596	.546
10	30	.953	.917	.886	.793	.734	.704
10	40	.964	.938	.915	.845	.801	.776
14	10	.852	.748	.657	.364	.184	.052
14	20	925	.871	.802	.661	.516	.453
14	30	.949	.913	.879	.769	.688	.629
14	40	.962	.934	.909	.825	.764	.720

we find that H=1.709. Table second shows that to attain this value of H we should commence to cushion at .844 of the return stroke. Suppose that, under otherwise the same conditions as before, we delay to begin cushioning until .931 of the return stroke is accomplished, c will then equal 3, and H will be found to

be 1.685, which is 1.4 per cent. less than in the first case.

Again, suppose a condensing engine in which $\frac{p_1}{p_2}=14$, $\frac{v_2}{v_1}=40$, and $r=10$, then, for the best working, $c=11.92$, and the point for beginning compression is .720 of the return stroke. Under these conditions, H=2.4783. Now, let the compression point be varied so that the back pressure at the end of the return stroke shall be four times what it was during exhaust, or, in other words, so that $c=4$, then we find that H=2.4245, which is more than two per cent. less than in the preceding case. Again, suppose an engine in which $\frac{v_2}{v_1}=10$, $\frac{p_1}{p_2}=6$, and $r=\frac{3}{5}$, then we get 2.7 per cent. more work from the same quantity of steam by closing the exhaust at .785 of the return stroke, the most advantageous point, than we would, should we cushion so as to carry the pressure to the initial.

In order to show the effect of clearance on the efficiency of engines having the exhaust closure properly regulated, the following cases have been assumed, and the value of H worked out for each case. The ratios of pressure and of expansion are the same in each instance, viz., $\frac{p_1}{p_2}=6$ and $r=4$. The ratio $\frac{v_2}{v_1}$ is different for each case, ranging from ten, in the first example, up to infinity in the fifth, where there is no clearance whatever. The values of c and H are given in the second and third columns respectively.

$\frac{v_2}{v_1}$	c.	H.
10	5.34	1.660
20	5.49	1.703
30	5.53	1.709
40	5.54	1.716
No clearance.....		1.720

The value of H in the fifth case is less than four per cent. greater than in the first. Excluding the value of H in the first instance, there is in no case a difference of one per cent. between any two of the remaining values. The last result shows the slight amount gained by dispensing with clearance entirely.

These examples might be extended much further, but enough has been done to show the use of the formula, and to illustrate how it may be applied to particular cases as they occur.

MEASUREMENT OF FLOW OF WATER IN DITCHES.

By H. N. PIERCE, '85, School of Mines, Columbia College.

Written for Van Nostrand's Magazine.

There appeared in the January number of the Magazine, a valuable paper on the above subject, by Mr. Aug. J. Bowie, Jr.

After a discussion of the "Miner's inch," the author takes up "Flow of water in open channels," and after stating that there is no generally accepted formula for determining the velocity of water in open channels—the older formulæ being based on data which ignore the important factor of the nature of the bed and sides of the channel,—he states that hydraulic engineers are compelled to rely for the correctness of *calculated* results, on a few known laws, in combination with experimental data, which latter, though all important, are restricted, and therefore of uncertain application.

Adopting the Chezy formula for mean velocity

$$v=c\sqrt{r\,s}$$

he naturally premises

$$Q=ac\sqrt{r\,s}$$

notating his symbols as follows:—

Q=quantity in cubic feet per second, discharged,

a=effective area of cross-section in sq. ft.

r=hydraulic mean depth in feet,

s=fall of surface in unit of length,

c=coefficient covering all common losses.

It is the object of the rest of the paper to establish by an analysis of the larger ditches on the Pacific coast, a mean value—or approaching limits of value—

for the experimental coefficient, c, and after considering all losses, Mr. Bowie adopted a value ranging from 31 to 45. a

In the April number of the Magazine (page 289) under the same title, is paper by Mr. Chas. E. Emery, Ph. D.

It is a criticism of Mr. Bowie's paper in the January number, and maintains that he (Mr. Bowie) has used r as the average depth of the stream, and *not* as the hydraulic mean depth, in the application of his formula

$$Q = a\,c\,\sqrt{rs}.$$

Mr. Emery then proceeds to apply the formula as he thinks it should be, and obtains values for c, averaging nearly three times as high as those of Mr. Bowie, from which he corrects the final formula to

$$Q = 109 \text{ @ } 116.5\ a\ \sqrt{r\,s}$$

in place of Mr. Bowie's calculation

$$Q = 31 \text{ @ } 45\ a\ \sqrt{r\,s}.$$

Let us take the Texas Creek branch ditch and its flume. It is the only case where Mr. Bowie has noted the discharge per second, the cross-section area of the flow, and the fall per unit of length.

When only the area is given the form of the channel is of some doubt, but we are quite safe in assuming that the sides of the channel slope at 60°.

It is a well-known fact that where the form of a channel is the half of any regular pōlygon and flowing full, the hydraulic mean depth is one-half the greatest depth, but under no other conditions. If the slopes were carried up at the same angle, the depth might vary from two to four feet, but the hydraulic mean depth would remain practically constant.

Mr. Bowie, however, says that the ditch was running about full, and taking this to mean that the section is a half hexagon, we have for the hydraulic mean depth 1.4 feet, which substituted in the formula gives a value of $c = 33.2$.

For the flume in connection with this ditch, the value of r is known with certainty to be .9 feet, giving a value of $c = 58.7$.

If these results are taken to the nearest whole number, they agree exactly with Mr. Bowie's figures and are perhaps sufficient to show how seriously Mr. Emery is in error.

Students of the School of Mines take a lively interest in discussions of this character, as it gives us an opportunity (by following out the investigations) to practically test the knowledge we are gaining at the School.

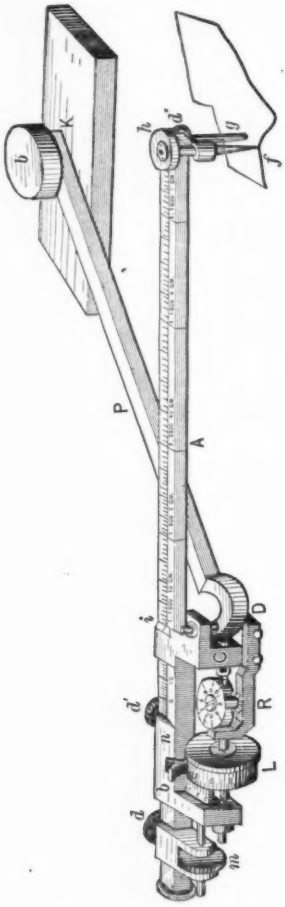
DIRECTIONS AS TO THE USE AND A THOROUGH TESTING OF CORADI'S PLANIMETER.

Translated by J. S. ELLIOTT.

1. Before using your instrument, be certain that it is in good order. The graduated "roller" L must have a barely perceptible play in its bearings. The vernier should not touch the "roller" graduation, and it should not be so far from the same that a good reading becomes difficult.

It is well to run, at times, a thin piece of letter paper between the two, so as to get rid of any dust that may have lodged between them. The register wheel R must revolve easily, and have sufficient play with the worm of the "roller." The axis D of the pole arm P should also turn easily, but on no account should it have the slightest play in its bearings. Make certain of this by placing pole arm and movable arm A parallel, and then try to move the pole arm up and down; further than a certain flexibility, no motion should take place. Both arms, as well as the pencil, should be protected from any bending. Great attention is to be given to the conservation of the "roller" rim, as it is the most important part of the instrument. Avoid all contact of the same with the naked fingers on account of rust specks. If fingered, it should be carefully wiped off in the direction of the axis with a piece of chamois leather. Remove at intervals the old clotted oil from the bearings. To do this, and at the same time avoid taking the instru-

ment to pieces, prop the frame so that the "roller" swings freely, and draw around the bearing of the axis a fine linen thread dipped in petroleum, then use on the bearings a sharpened splinter dipped in the best oil.



2. To find the area of some figure to a certain scale, say 1 : 1200, shove the movable arm in its socket, until it is easy, by means of the micrometer screw m to set the vernier n at the number (220.6 in this case) found in the table pasted in the instrument box; then clamp the socket with the screw d'. The desired areas should be stretched on a smooth drawing board, with no inequalities to obstruct the running of the "roller."

3. Place now the pole slab K near the desired area, and the pole ball in its proper receptacle; a hasty circuit should convince you, that for the chosen position of the pole there will be no obstruction.

4. Place the pencil on an easily distinguished point of the circumference, and to reduce to a minimum the tracing errors, it is well to so choose the starting point that the two arms are about at right angles to each other. You can now either take a note of the reading of register wheel, "roller" and vernier, or by slightly shifting the pole slab, bring the zero points of the "roller" and vernier in line. Let, for instance, the register wheel show 3 and the roller graduation be at zero.

5. Trace carefully around the circumference in the direction of the hands of a watch, until you regain the starting point. The instrument rotates around the "pole," whilst the "roller" acts now with a sliding, then with a back and forward rolling motion. It is well to use a straight edge on all straight lines of the circumference; it does, however, sometimes lead to positive or negative tracing errors, whilst when done freehand, the alternating positive and negative errors to some extent cancel each other. Furthermore, when using a straight edge, care must be taken to have no lateral pressure on the pencil button h, for it would result in a tracing error by reason of the flexible movable arm changing its position with regard to the pencil point.

6. The circuit made, take your reading. The vernier reads to tenths, and one complete revolution of the "roller," and one division of the register wheel, are each worth 1,000 vernier units.

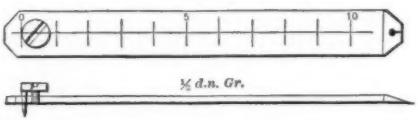
Suppose that the register wheel reads between the 4th and 5th division and the "roller" graduation reads 137. The "roller" has then moved forward by $1000+137=1137$ vernier units. Multiplying this by 10 sq. ms., the value of the vernier unit, the desired area is 11,370 sq. ms. If, before making the circuit, the graduation has not been set at zero, a reading should be taken and subtracted from the second reading, and the difference multiplied by the value of the vernier unit.

7. With large areas whose circuits cannot be traced with one "set up" with the pole slab outside, place the pole slab in the middle, and trace the circuit *against* the hands of a watch.

In this case it is advantageous to set both "roller" and register wheel on zero before making the circuit, as thus, errors are sooner eliminated. The resulting reading must be subtracted from a constant quantity found on the movable arm or in the table, and the difference multiplied by the value of the vernier unit. You wish, for instance, to find the area in feet of some plat: your reading is 1832; subtract this from constant quantity 20,555, and multiply difference by 0.0001 sq. ft., giving $1.\frac{8,7,2}{1,0,0,0}$ sq. ft. If during the circuit, the register wheel has made one complete revolution forward, 10,000 must be added to the reading.

With large areas, where the angle made by pole slab, roller and pencil point is constantly over 90°, the register wheel will move backwards; in such a case,

Fig. 1



subtract the reading from 10,000, add remainder to the constant quantity, and the sum of the two multiplied by the vernier unit value will give the desired area.

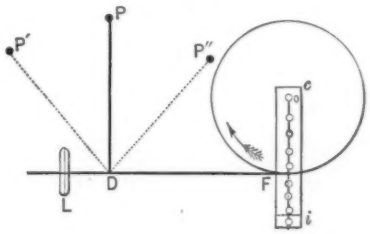
Many tracings of some figure are necessary for a scientific testing of the instrument, and as all tracing errors should be eliminated, mechanical devices may be used with great advantage. Among these the so-called "check-ruler," Fig. 1, deserves especial notice.

It is a small brass scale with ten 1 centimeter divisions. At the intersection of the zero division with the line, the length of the scale is stuck a needle through a small hole; at the other intersections are small indentations to hold the pencil point of the planimeter. One end of the "ruler" is beveled and has an index line to locate the starting point of one of the test circles, shown as it is in the test circle by a produced radius. The use of this device is best understood from Fig. 2.

The "ruler," in fact, is to be used as a means of tracing a perfect circle. Setting the pencil point in any one indentation, means tracing a circle whose area is a function of the distance between said indentation and the needle. The needle stuck in the paper acts as a pivot. As to the objections that the circle is too favorable a figure for the testing of the planimeter, it may be replied that if the examination includes all the requirements given further on, and has stood them all well (a difference of readings of 2 to $2\frac{1}{2}$ vernier units being regarded as permissible), the instrument will give a good and trustworthy value of any and all figures, bounded as they may be, *i. e.*, within the given limits of error.

It is held that mechanical devices eliminate all error. This is altogether wrong, as shown by numerous experiments. If, for instance, when using the check-ruler

Fig. 2



as a radius, the pressure on the pencil is not tangential, a certain bending of the movable arm takes place, although the pencil point cannot leave the periphery. The result is a tracing error of some consequence.

It is therefore recommended to lightly load the pencil, as well as the center of rotation of the "check-ruler," and to guide only with the "check-ruler."

The planimeter should be tested for the following requirements in the given order:

1. The instrument should be in general good order.

2. The graduation of the "roller" should be accurate and concentric.

3. With repeated tracings the readings should be the same, and the graduation should be concentric with the rim of the "roller."

4. The readings for different posi-

Scale Proportions.	Value of the Vernier-Unity.	Readings for one Circuit of the Circles with Radii of from 1 cm. to 10 cm.									
		1 cm.	2 cm.	3 cm.	4 cm.	5 cm.	6 cm.	7 cm.	8 cm.	9 cm.	10 cm.
1 : 500 1 : 1000 1 : 2000 1 : 4000	2.5 10. 40. 160.	0,03,14	0,12,56	0,28,27	0,50,26	0,78,54	1,13,097	1,53,93	2,01,06	2,54,47	3,14,16
1 : 500 1 : 1000 1 : 2500 1 : 5000	2. 8. 50. 200.	0,03,92	0,15,7	0,35,33	0,62,83	0,98,17	1,41,37	1,92,41	2,51,33	3,18,09	3,92,70
1 : 625 1 : 1250 1 : 2500 1 : 5000	2.5 10. 40. 160.	0,04,9	0,19,63	0,44,18	0,78,54	1,22,71	1,76,71	2,40,51	3,14,16	3,97,61	4,90,85
1 : 750 1 : 1500 1 : 3000	5. 20. 80.	0,03,53	0,14,13	0,31,80	0,56,54	0,88,35	1,27,23	1,73,17	2,26,18	2,86,27	3,53,42
1 : 750 1 : 1500 1 : 3000	2.5 10. 40.	0,07,06	0,28,26	0,63,61	1,13,09	1,76,71	2,54,47	3,46,34	4,52,36	5,72,54	7,06,84
1 : 1000 1 : 2000 1 : 4000	5. 20. 80.	0,06,28	0,25,13	0,56,54	1,00,52	1,57,08	2,26,19	3,07,86	4,02,12	5,08,89	6,28,32
1 : 500 1 : 1000 1 : 2500 1 : 5000	1. 4. 25. 100.	0,07,85	0,31,41	0,70,68	1,25,66	1,96,34	2,82,74	3,84,82	5,02,66	6,36,18	7,85,40
1 : 1250 1 : 2500 1 : 5000	5. 20. 80.	0,09,81	0,39 27	0,88,35	1,57,08	2,45,43	3,53,42	4,81,02	6,28,32	7,95,19	9,81,75

1 : 2500	10.	0,19,63	0,78,54	1,76,71	3,14,6	4,90,85	7,06,84	9,62,05	12,56,64	15,90,39	19,63,50
1 : 1000	2.	0,15,70	0,62,83	1,41,37	2,51,33	3,92,70	5,65,48	7,69,65	10,05,31	12,72,35	15,70,8
1 : 2500	12.5										
1 : 5000	50.										
1 : 1440	20.	0,06,51	0,26,06	0,58,62	1,04,24	1,62,86	2,34,50	3,19,18	4,16,96	5,27,63	6,51,44
1 : 2730	40.	0,05,85	0,23,41	0,52,67	0,93,64	1,46,39	2,10,69	2,86,82	3,74,57	4,74,03	5,85,35
1 : 6250	200.	0,06,13	0,24,54	0,55,22	0,98,17	1,53,36	2,20,88	3,00,63	3,92,7	4,96,98	6,13,56
1 : 1820	20.	0,05,20	0,20,81	0,46,82	0,83,24	1,30,08	1,87,28	2,54,95	3,32,96	4,21,38	5,20,31
1 : 2400	40.	0,04,52	0,18,09	0,40,71	0,72,38	1,13,09	1,62,86	2,21,66	2,89,52	3,66,43	4,52,39

This table gives the values of the vernier units (reduction factors) for the most commonly used scales, as well as the readings, got by tracing around the ten circles, whose radii are given in the "check rules."

tions of the pole slab should be constant.

5. The readings when tracing a figure both ways should be constant.

6. The given value of the vernier unit should be right for the adjusted length of the movable arm.

7. The given constant quantities should be right.

For. 1. See what has been previously said.

For. 2. Test the vernier at every 5th division of the "roller" graduation. If the tests are satisfactory, it may be taken for granted that the graduation is accurate as well as concentric.

For. 3. Choose for this important requirement the greatest length of the movable arm 1 : 1000, and place the instrument in the position shown in Fig. 2 (the two arms at right angles with each other). Take now some radius on the "check-ruler," giving a circle whose repeated tracings will eventually bring every 2d or 3d division in the readings. Chosen, for instance, 6 cms. as radius, you will get 1130.9 as reading. Trace this circle some 60 times, until every other division line has come into the readings. The difference between greatest and least readings should not exceed $2\frac{1}{2}$ vernier units.

If the readings starting from one point, first increase and then decrease in such a way that the least and greatest readings are some 50 "roller" divisions apart, we have a proof that the "roller" rim and graduation are not concentric. If, however, the errors show up irregularly, it points to a malformation of the "roller" rim. These two errors can be removed only in the workshop.

For. 4. Take from the "check-ruler" a radius giving an average-sized circle, and trace it with the pole slab in the 3 positions given in Fig. 2, P P′ and P″. If the reading gives for the nearest pole-slab position too great an area, the right end of the roller axis must be brought nearer to the movable arm by turning the cylinder C, and in the opposite case, should be moved away by the same means, seeing carefully to it in both cases that the play of the register wheel in the worm becomes neither too great nor too small.

Test No. 4 should be repeated for the various lengths of the movable arm; a

deviation for any length shows that the movable arm has been bent, and the error should be removed the same way it arose. It is best for this purpose to begin with the shortest value of the movable arm; set the "roller" axis parallel by turning the cylinder C, so that the readings will be equal for different positions of the pole slab. Test now for the next length of the movable arm, and try to get the same result by carefully binding the movable arm. If your reading is too great for the nearest position of the pole slab, you must bend the right end of movable arm away from the pole slab. With any kind of careful handling, though, a bending of the movable arm should not occur, made as it is of cold-drawn German silver.

For. 5. This error occurs with planimeters whose "rollers" are fixed, and whose pole arm axes are detachable, and is owing to too much play of the "roller" axis, and to a malformation of the "roller" rim. Test for it by taking the longest radius (10 cms.) of the "check-ruler," and trace a complete circle both ways. Both readings should be equal. This error is especially injurious when tracing long narrow figures.

For. 6. First examine the "check-ruler" to see that the graduation is right, and that the indentation as well as the center of rotation are exactly at the intersection of the divisions with the longitudinal line; see also that the needle is perpendicular. Now calculate the areas of the 10 circles traceable with the "check-ruler," and be sure that the resulting readings check with your calculations. Lengthen or shorten your movable arm according as your readings are too great or too small. At the same time the following test may be attempted—a favorable result meaning that the instrument may be used for definite work. Draw accurately a square of known area as large as the planimeter can trace around. Trace the same with different positions of the instrument, and convince yourself that the readings check with the computed area. Divide the square into 2 equal triangles, and trace each with different positions of the instrument; the readings should be equal and their sum equal to reading of the whole. Further subdivisions may also be attempted. This test serves also to determine the individual mean tracing error.

For. 7. For this test use a small mechanism sent with the instrument on request. It fixes movable arm and pole arm at any angle you please, so that circles of any size may be described around the pole slab. Place the pole slab on a line representing the diameter of various sized circles with the pole vertically over the line. Lay off on this line with the pencil point the different diameters, measure them and compute the areas of circles they represent. Let A = computed area of any one circle, and V = value of vernier units, then $\frac{A}{V}$ + reading got by tracing the same circle = constant quantity.

MEASUREMENT AND FLOW OF WATER IN DITCHES.

By CHAS. E. EMERY, Ph.D.

Written for Van Nostrand's Engineering Magazine.

Referring to the article on the above subject, by Mr. Bowie, in the January number of the Magazine, I will state that my note in the April number stands corrected by that of Mr. Browne, in the May number. It appeared clear on the first reading of Mr. Bowie's paper that the expression in regard to the depth of the La Grange ditch, at top of p. 35 of the January number, admitted of but one construction, and a constant was worked backward from the data given, on that basis, but a second reading of the paper, in connection with Mr. Browne's note, shows the intention of the writer.

THE STATE OF TOWN DRAINAGE IN RUSSIA.

By A. v. ABRAMSON.

Translated from "Gesundheits-Ingenieur" for Institution of Civil Engineers.

The question of drainage has hitherto received but little attention in Russia. The principal towns are none of them thickly built over, and only the largest of them — St. Petersburg, Moscow, Odessa and Kiev—can lay claim to a regular water-supply; while with the single exception of Odessa, which is in many respects a model Russian town, they are all ill-paved and badly provided with water.

This matter first attracted notice in respect to St. Petersburg, in which city the mortality is appaling. After a considerable portion of the town had been supplied with Neva water, and when water-closets had been almost universally employed, the evils of cesspools, which had to be emptied by casks carted daily through the streets to the suburbs, became glaringly manifest. Owing to its low-lying marshy situation, and the proximity of the subsoil water to the surface, the question of sewer construction is here one of great difficulty, and the pneumatic system appeared to present important advantages. Very satisfactory trials of Captain Liernur's plan have been carried out, at the experimental station on the Semjonow Square, and this system, in spite of the complaints made respecting it in certain towns in Holland, has many advocates. Bourow, the Russian engineer, is now trying another pneumatic system, which carries away their contents direct from the cesspools by means of a vacuum created in a system of pipes with which the cesspools are placed in connection. His investigations, however, are not yet completed, and the question, so far as St. Petersburg is concerned is still in the experimental stage.

Moscow, on the other hand, has pronounced in favor of the water-carriage system; all the preliminary matters have been arranged, and it is understood that a comprehensive plan of drainage prepared by Herr Hobrecht has been accepted. The execution of the work has been delayed by the proposal of the Governor-General, Prince Dolgoroukou, that the Government should undertake its direction, as a work of such high importance, and that for this purpose a representative committee would be appointed from the town authorities, the Zemstwo, the Government, and the Society of Engineers.

Odessa also enjoys the advantage of a water-carriage system, which is not yet so complete as it might be in the outlying suburbs. Householders are not compelled to connect with the sewers; each one is free to do as he chooses; and a further defect of the scheme of drainage is that the main outfall discharges into the center of the harbor, close to the public bathing-establishments.

In Kiev, the oldest town in Russia, this matter has come to the front from the discovery that, in spite of its naturally healthy position, on the summit of lofty hills, below which flows a large and rapid river, the Dneiper, the death-rate here averages thirty-eight per thousand. A commission of engineers and physicians was appointed to inquire into this subject in 1879, and in their report they attributed the above state of things to the insanitary condition of the town, and recommended the immediate adoption of the water-carriage system, at an estimated cost of 2½ millions of roubles (about £400,000), or from £2 10s. to £3 per head of the population. Their views were adopted, and the necessary preliminary works were ordered.

There is a law in Russia which prohibits the pollution of public watercourses, and the Kiev authorities are endeavoring to obtain permission to discharge the sewage at a sufficient distance from the town, into the river Dneiper, which at the point proposed has a velocity of 0.75 meter (29.5 inches) per second, and a flow of over 200 cubic meters (44,000 gallons) per second. To take the water to a point where it could be profitably employed in irrigation, would necessitate a lift of 80 meters (262.4 feet), and would so increase the

expense as to render this method of drainage impracticable: the success of the scheme depends, therefore, on the permission being granted to drain into the river.

At Warsaw a water-carriage system, designed by Mr. W. Lindley, M. Inst. C. E., is well advanced towards completion; and though the policy of taking all the sewage into such a small stream as the Vistula has been disputed, the town will shortly be in possession of a thorough system of drainage.

In addition to the towns already mentioned, the subject is receiving attention in several places of lesser importance, as, for instance, Charkow, though there the matter has scarcely got beyond the phase of discussion, at the meetings of the town council.

This momentous question is, however, being widely considered, and efforts are being made to extend the knowledge of its importance throughout Russia. As one who has taken the lead in drawing attention to the subject, the author follows with careful interest all that is taking place in neighboring countries.

SPONTANEOUS DECOMPOSITION OF EXPLOSIVE GELATINE.

By CHARLES E. MUNROE, S.B. (Harv.)

From the Journal of the American Chemical Society.

Several instances of the decomposition of explosive gelatine on keeping, or after long exposure to moderate temperatures, have been reported, but I have yet met with but one of these cases in which the products of the decomposition have been stated. Gen. H. L. Abbot, in a prefatory note to Addendum I, Report on Submarine Mines, states that "all the samples of the explosive gelatine remaining on hand after the trials detailed in the Report, have undergone spontaneous decomposition, separating into cellulose and free nitro-glycerine with the copious evolutions of nitrous fumes. This change occurred during the winter and spring of the current year (1881–1882), and was not caused by any exposure to high temperatures while in store."

A case of spontaneous decomposition of a small amount stored freely exposed to the air, in a room of fairly even temperature and dryness, has occurred under my own observation. The camphorated explosive gelatine was wrapped in paraffine paper, and then in light brown Manilla paper, and laid on the shelf. After something more than one year's exposure it was found, in the early winter, to be giving off nitrous fumes (which had stained and attacked the wrapping paper), and to have shrunk considerably in volume, while the outside of the paper was covered with congeries of fine crystals. The odor of camphor was still quite strong. The mass was immediately put into a vessel of water. It was found to be friable, and, after a short immersion, disintegrated. The camphor odor soon disappeared, and the water became of a straw color, gave a strong acid reaction, and showed traces of nitrous acid, but no nitric acid. On evaporation of the filtered liquid, oxalic acid crystallized out in quantity, and on evaporation of the "mother liquor" on the water bath, a sugar-like mass was obtained, which gave the glucose reaction with Fehling's solution. The paraffine was regained unchanged, and the paper was recovered, but in a flocculent condition, and with the color bleached from the brown. Careful search failed to reveal the presence of glycerine, nitro-glycerine, or gun-cotton.

The cellulose from the gun-cotton could not well be detected (if it existed) in the presence of so much flocculent cellulose from the paper. In reporting these observations I am not unmindful of the fact that some changes may have taken place during immersion, but it can easily be understood why I preferred it in that position.

The results obtained by de Luca in his "Researches on the Spontaneous Decomposition of Gun-Cotton," *Comptes Rendus* 59,487, *Sept.* 12, 1847, are inter-

esting in this connection. Gun-cotton decomposes most rapidly when heated to 50° on a water bath, next by direct sunlight, more slowly by diffused light, and very slowly in darkness. The gun-cotton first shrinks to one-tenth of its original volume, next it begins to become gum-like and sticky, then it swells; during all these phases it gives off nitrous fumes, but especially during the last. For the fourth phase the gas ceases to be evolved, and the mass becomes brittle, and of a light color like sugar. The products are nitrous compounds, with formic and acetic acids in the state of a gas, and an amorphous, porous, sugar-like body, almost entirely soluble in water, and containing an abundance of glucose, gummy matter, oxalic acid, a small quantity of formic acid, and a new acid of which he obtained the lead and silver salts for later examination. From 100 grains of gun-cotton he obtained about 14 grains of glucose.

In discussing the stability of nitro-glycerine (which is the other component of explosive gelatine), A. Brull, in *Etudes sur la Nitro-glycerine et la Dynamite*, *Fig.* 26, 1875, says: "Nitro-glycerine which retains traces of acid is not stable. In general the decomposition is extremely slow and tranquil. It disengages at first nitrous fumes, and the liquid takes a greenish color; then it generates nitrogen protoxide, carbon dioxide and crystals of oxalic acid, and after some months the entire mass is found to be converted into a greenish, gelatinous mass, composed of oxalic acid, water and ammonia. Sometimes, if the temperature is quite high—if, for example, the nitro-glycerine is heated by the sun, the decomposition is more active. Very rarely it causes an explosion."

The source of difficulty, then, seems to be in the presence of free acid, and this will probably be found in the gun-cotton used, for it is difficult to purify soluble gun-cotton completely.

THE FLOW THROUGH SUBMERGED OUTLETS.

By ALFRED SALLES.

Translated from "Annales des Ponts et Chaussées."

The delivery through submerged sluices, those in which the sill is below the water on the down stream side, may be calculated by the aid of two formulas; one of them due to M. Mary, and the other to M Lesbros. The writer has had occasion to apply them in case of the Bazacle Dam upon the Garonne at Toulouse, and the object of the present note is to record the results obtained.

In 1860 M. Mary published in his *Cours de Navigation Interieure* a formula which may be written

$$Q = m\,L\,H'\sqrt{2g(H-H'+h)}$$

in which L is the length of the sluice, H the height of the water on the up stream side above the sill of the sluice, H′ the height of the surface on the down stream side above the same level, and h is the height due to the velocity of the current on the up-stream side. Of the coefficient m the author says, although the value of m has not been determined by any known experiments, we may assume it to be about 0.8.

According to the accounts collected by the *Service des inundations*, notably by Messrs. Lanteires, Endres and Gros, the flow on June 23d, 1875, at the Bazacle Dam was from 6,000 to 7,000 cubic meters per second. It had been determined by the delivery of the Garonne above, and they found fH a value of $5^m.95$ to 6 meters, and for H′ a value of 5 meters. In adopting the mean value of 6,500 cubic meters for Q the writer finds that the velocity of the river above should be $3^m.40$ per second, which gives for the value of $h = 0^m.59$. The length of the dam is 283 meters. This for the value of m

$$m = \frac{6500}{283 \times 5\sqrt{2g\,(6-5+0.59)}} = 0.82$$

which will accord with the estimate of M. Mary.

Taking Q=7000 cubic meters, we get for the velocity $u = 3.6$ and for $h = 0^m.66$.

The corresponding value of m is 0.87. If Q=6000 cubic meters, u becomes =3.20 and $h=0^m.52$. The value of m then falls to 0.77

M. Lesbros' formula is

$$Q=m' L H \sqrt{2g (H-H')}$$

H is the height of water level in the up-stream side measured above the sill of the sluice and measured to the surface of still water. H' is the height of the water level down stream above the sill of the sluice, but measured to the lowest point of the hollow of the liquid vein. m' is a coefficient varying between 0.430 0.605 according to the value of $\frac{H-H'}{H}$.

The above considerations indicate that the formula of M. Lesbros, although serviceable for sluices for water wheels and irrigation canals, should not be applied without examination to the submerged dams of rivers. The heights of 6 meters and 5 meters realized at Toulouse during the inundation of 1875, doubless fail to answer to the letter of the prescribed conditions, but they nevertheless deviate but little, and for

$$\frac{H-H'}{H}=\frac{6-5}{6}=\frac{1}{6}$$

the table of M. Lesbros gives a value of $m'=0.511$. If this were the true value, the quantity delivered at the Bazacle Dam would have been only

$$0.511\times 283\times 6\times\sqrt{2g\,(6-5)}=3843$$

cubic meters instead of 6000 or 7000.

In order to obtain a mean delivery of 6500 cubic meters m' should have a value of

$$\frac{6500}{283\times 6\sqrt{2g\,(6-5)}}=0.86$$

which is not far from the value determined above for m for the same delivery.

The writer believes that the formulas of Mary and Lesbros should be applied to the submerged outlets with the coefficient of about 0.80, conformably to the estimate of M. Mary, whose formula, perhaps too often forgotten at the present day, has been meanwhile confirmed by the experiments at the Bazacle Dam during the great flood of the Garonne in June, 1875.

THE SCOPE AND METHOD OF PETROGRAPHY.*

By J. J. H. TEALE, M.A., F.G.S.

From "Nature."

In considering the history of geology we are struck by the fact that towards the close of the last and during the commencement of the present century, when the science was taking rank as an important branch of human knowledge, petrography occupied a much higher position than it has at any subsequent period.

Werner, whose influence was almost unrivaled at the time to which I have referred, was a mineralogist, and his formations were therefore naturally based on the mineralogical characters of the different rocks. His observations were limited for the most part to his own district of Saxony, but he regarded his formations as sediments or precipitates from a universal ocean, and his numerous pupils, fired by his love of science and his intense enthusiasm, rejoiced in extending his classification to the districts with which they were severally acquainted.

The magnificent work of those who devoted special attention to the organic remains in the sedimentary deposits, and especially that of William Smith, the "Father of British Geology," had the effect of deposing petrography from the position which it held under the influence of Werner and his followers. It was clearly shown that the fossil contents of the strata were far more reliable as evidence of chronological relations than their lithological characters, and as soon as this became generally recognized, the reduction of the fossil-bearing rocks all over the world to something like definite order followed as a natural consequence.

The principle that strata may be identified by means of their fossil contents has

* Lecture delivered in the Woodwardian Museum, Cambridge.

not only proved applicable to the Secondary and Tertiary formations to which it was originally applied by Smith, Cuvier, and others, but it has been extended by Murchison, Sedgwick, Barrande, and others to the older rocks. Speaking broadly, there can be no doubt that over large areas the succession of the forms of marine life has been remarkably uniform from the Cambrian times down to the present, so that we have in the fossil contents of the different strata by far the most reliable means of determining chronological relations.

It is not surprising, then, that petrography has been comparatively neglected by geologists, for their main object during the present century has been to classify the stratified rocks which form so large a portion of the existing land surfaces.

At the present time, however, we are witnessing a great revival of interest in petrography, not only in this country, but all over the globe. This is due in part, no doubt, to the introduction of new methods of research; but it seems to me that there are other and more general causes. The clear recognition of the great principle with which the name of William Smith is so indissolubly united at once made it possible for a host of observers to do excellent work in every quarter of the globe. The interest awakened by the study of the geological structure of the most densely populated regions was akin to that which is felt by the geographical explorer of unknown lands. Until the main features of the geology of fossiliferous regions were described, it was not to be expected that observers would turn aside from a field of research in which they were certain to meet with success for the purpose of attacking problems which, after all, might prove to be insoluble. As time went on, the unexplored tracts in which fossiliferous rocks occur became more and more restricted, or more and more inaccessible, and when the old chaos of Grauwacke fell into order before the brilliant researches of Sedgwick, Murchison, and Barrande, geologists were placed in an entirely new position. They had conquered that portion of the world which was open to their special method of attack. A number of fortresses still held out, it is true, and many of these remain unsubdued at the present day. They will doubtless occupy the attention of those who are most skilled in the old methods of warfare for many years to come. At the same time I think it will be admitted on all hands that the brilliant successes of the old generals have left a large portion of the army with little to do. We must, therefore, look for other worlds to conquer.

Now, on taking a general survey of the subject-matter of geology it will be seen at once that we are profoundly ignorant on questions relating to the origin and sequence of volcanic rocks, the cause or causes of volcanic action, the mode of formation of the crystalline schists, and the origin of mountains. That these questions are really unsolved is proved by the difference of opinion which exists between competent observers. Another point which strikes one is, that if a solution of these problems be ever realized, it will be due in a great measure to the combination of field geology and petrography. This, it seems to me, will explain the great interest which is taken in the latter branch of science at the present day. If I am right in my opinion as to the present state of things, then we may safely predict that petrography will occupy as prominent a position in the immediate future of geology as palæontology has done in the past. In making this statement I trust it will not be thought that I am claiming too high a position for that branch of geology with which I am most intimately acquainted.

Let us turn now to a more detailed consideration of the scope and method of petrography. The rocks of the earth's crust form the subject-matter of the science. Now, these may be studied from two more or less distinct points of view —the descriptive and the ætiological. We may set to work to describe the rocks, that is, to ascertain and record every possible fact with regard to them; or we may endeavor to trace the succession of events which has culminated in the state of things which we actually observe. It is perfectly obvious that we cannot hope to attain any considerable success in the second branch of the subject until we have devoted a considerable amount of attention to the first.

Descriptive petrography then concerns itself with the chemical, mineralogical, and physical character of the individual rocks, and also with the distribution and mu-

tual relations of the different varieties. The last-mentioned branch of the subject occupies the same position in petrography as comparative anatomy does in zoology. It may therefore be termed comparative petrography.

When the history of the science comes to be written, it will be recognized that it is to the Germans we are especially indebted for our knowledge of descriptive petrography. The amount of work which has been done in Germany is immeasurably greater than that produced by other nations. For years past they have been steadily improving their methods of observation, as well as observing and recording facts. Moreover, they have been training petrographers who are now scattered all over the world. The Americans especially have availed themselves of the laboratories of Rosenbusch and Zirkel, and almost every Annual Report of the American Survey now bears witness to the influence of Germany, from a teaching point of view, on the growth of petrographical science. In this sketch, of course, I am only calling attention to the broad facts of history as far as regards the special branch of descriptive petrography. Many observers in France, England, and America have done independent work of the very highest order, and to England especially belongs the credit of having, in the person of Sorby, determined to a very large extent the introduction of the modern methods of microscopical research.

Consider now what is involved in the description of any particular rock, and take, for example, a specimen of the Whin Sill, that mass of basic igneous rock which plays such an important part in the Carboniferous region of the North of England.

The rock is dark gray or bluish-gray when freshly exposed. In texture it varies from compact to coarsely crystalline, the most common variety being one in which the individual constituents are just recognizable by the naked eye. Its specific gravity varies from 2.90 to 2.95. Its chemical composition is shown on this table. (Table referred to.) We have now to consider its mineralogical composition. In the determination of minerals in rocks we use physical and chemical methods. Color, general appearance, hardness, cleavages, specific gravity, crystalline form, fusibility, and flame coloration are some of the most important physical properties available for the determination of minerals in rocks when they can be examined microscopically. In thin sections we can use color, general appearance, cleavages, form, and also the many properties which are brought out by the use of parallel and convergent rays of polarized light. Chemical tests may be applied both to microscopically recognizable minerals and also to those which can only be observed by the use of thin sections or minute particles and the microscope. The latter are generally referred to as micro-chemical tests.

By applying these methods, some of which will be more fully explained in the subsequent lectures, we can prove that the rock of the Whin Sill is composed of felspar, pyroxene, titaniferous magnetic iron ore, quartz in the form of grains and also as a constituent of micro-pegmatite, apatite, pyrite, brown hornblende, mica, and some green decomposition products. Apatite, pyrite, hornblende, and mica occur only in very small quantity, and cannot be said to form any appreciable portion of the rock.

In order to give a complete petrographical description, however, it is necessary that we should not only know what minerals are present, but also that we should know the precise composition of each and the relative abundance of the different species. Information on these points can only be obtained by isolating the different constituents of a rock and analyzing them separately. Methods of isolation will be described in subsequent lectures. The most important are those which depend on the use of heavy solutions, the magnet and electro-magnet, and various chemical re-agents, especially hydrochloric and hydrofluoric acids. The chemical composition of each of the three principal constituents of the Whin Sill is represented on these tables. (Tables referred to.) Now, having obtained a knowledge of the composition of the principal constituents of the rock, it becomes possible to determine with a very fair amount of accuracy the relative proportions of these constituents by calculations based on the bulk analysis of the rock.

There is yet another point of great importance to which attention should be paid in subjecting a rock to an exhaustive

examination. Owing to the brilliant researches of Sandberger, it is beginning to be recognized that many of the heavy and so-called rare metals are present in ordinary rocks in minute quantities. Until recently we have been disposed to regard these substances as occurring only in mineral veins and in the deeper portions of the earth from which the mineral veins have been supposed to derive their supply of material. Now it is beginning to be clearly recognized that these substances are very widely distributed, even in the superficial crust of the globe. As an illustration of the interest and practical importance of the subject above referred to, I may call attention to the important work by Dr. Becker, on the "Geology of the Comstock Lode," recently published by the U. S. Geological Survey. This lode, the yield of which is supposed to have sensibly affected the bullion markets of the world, occurs in a region which is remarkable for the extreme development of igneous rocks (diabase, diorite, andesites, &c.), and for the widespread alteration to which these rocks have been subjected. The bisilicates, especially, have been affected by this alteration, and for immense distances they have been entirely replaced by a green chloritic mineral.

Most careful assays have been executed, under the supervision of Dr. Becker, for the purpose of determining the amount of bullion in the fresh and unaltered rocks, and the relative amounts of gold and silver. He says: "By comparison of the different assays it appears that decomposed diabase carries somewhat less than half as much silver as the fresh rock. When the decomposed rocks are pyritous the experiments made do not indicate any essential diminution of the gold contents. This fact, however, is quite possibly due to irregularity in distribution and the minuteness of the quantities of gold to be determined. As the decomposition of the rock in question has proceeded at a great depth beneath the surface, it is highly unlikely that silver should have been extracted unaccompanied by gold. Much of the decomposed rock, too, is nearly free from pyrite, and had the gold contents of such specimens been determined, a smaller percentage would probably have been found. The omission (to select specimens free from pyrite) was not detected until it was too late to resume the investigation. So far as quantitative relations are concerned, the silver only can be relied on, though the qualitative detection of gold as well is both interesting and important."

Another point of great interest was determined by Dr. Becker. He isolated the felspar and the augite of the diabase and tested both from silver. He found that for equal weights the augite was eight times as rich as the felspar substance, and as the latter contained some augite, this appears to furnish substantial proof that the silver is a constituent of the augite.

Having subjected a rock to exhaustive chemical and mineralogical examination, it next becomes necessary to compare it with other rocks, and to give it a name. The subject of nomenclature is a very difficult one. It is much to be regretted that notwithstanding all that has been done in descriptive and comparative petrography, we are still far from having any system of classification which is capable of general acceptance. Indeed, we are not agreed as to the first principles on which a classification of rocks should be based. The German petrographers, in most cases, adopt at the outset a principle which we cannot accept. They divide igneous rocks into older and younger: the former including all those which they regard as pre-Tertiary, the latter all those which are of post-Cretaceous age. The division is based, of course, on the assumption that the conditions of eruption in pre-Tertiary times were essentially different from those which have prevailed since. There seems, so far as we can judge, little or no ground for this assumption. The few facts which do at first sight lend support to it appear to be equally capable of explanation on the other hypothesis. The typical pre-Tertiary rocks of the German system are the granites, diorites, gabbros, diabases, and syenites. Now there is reason to believe that these are all plutonic rocks; in other words, that they are the result of slow consolidation beneath the surface, and therefore under great pressure. If this view be correct, then their exposure at the surface can only occur long after their formation, and the fact that the majority of those known to us should be of pre-

Tertiary age, as Lyell long ago pointed out, need occasion no surprise.

Again, it must be remembered that the mere association of eruptive rocks with pre-Tertiary deposits is no proof in itself that the former are of pre-Tertiary age, and also that many competent observers believe that these are clear cases of Tertiary granite, diorite, diabase, and gabbro.

The igneous rocks, which are regarded by the German petrographers as especially characteristic of the post-Cretaceous period, are the basalts, andesites, trachytes, and rhyolites; in other words, the surface-products of volcanic action. That these should be mainly Tertiary, and that they should differ to a certain extent from their pre-Tertiary equivalents in consequence of alteration, is only what might be naturally expected. This, however, is not sufficient to justify the refusal to give the same name to different specimens of one and the same rock merely because they have been produced at different periods; and the work of Allport, Bonney, Geikie, and others has proved that there are basalts, andesites, and rhyolites of Palæozoic age which are identical in structure, composition, and mode of occurrence with modern rocks.

In the absence of any generally recognized system of nomenclature it becomes difficult to assign a name to the rock of the Whin Sill. It is a holo-crystalline rock composed essentially of plagioclase, pyroxene, titaniferous and magnetic iron ore. In sections the felspar occurs in lath-shaped forms. To such a rock, provided it be of pre-Tertiary age, Rosenbusch would give the name diabase. We are inclined, on the other hand, to call the rock a dolerite. The important point for the student to remember, however, is that in the present unsettled state of nomenclature his primary duty is to make himself familiar with the structure and composition of the various rock types. The question of names is, after all, only of secondary importance, provided we remember that in looking at the facts through the medium of an unphilosophical nomenclature we may so distort them as to fail to realize their true forms and relations.

Consider now the ætiological aspect of petrography. Most of us are so constituted that we cannot rest satisfied with a mere description of facts; we almost instinctively endeavor to discover what we call the origin of things. This, after all, merely consists in tracing back as far as possible the chain of events of which the object or phenomenon in question represents the last link. The search after causal relations in the organic world has led to the introduction of a principle which is now recognized as one of the greatest importance in almost every branch of human knowledge. Changes in the characters of organisms are now admitted to be determined by two factors —the inherent properties of the organism and the influence of surrounding circumstances. A very little consideration will serve to show that the changes which occur during and subsequent to the development of minerals and rocks are determined by two allied factors.

Take the case of crystallogenesis. It is not difficult to see in a general kind of way that the characters which a crystal possesses have been determined (1) by the inherent properties of the crystallizing substance, and (2) by the influence of surrounding circumstances—of the environment. When we examine thin sections of rocks, furnace-slags, or the refuse products of glass-works, we frequently find a number of bodies which are intermediate as it were between glass and true crystals. These have been carefully examined and admirably described by Herrmann Vogelsang, who has also succeeded in producing many of them by artificial means. As they serve to illustrate in a very striking way the principle above referred to, a short description of Vogelsang's experiments will not be out of place.

The crystallizing substance finally selected by Vogelsang for the purpose of his experiments was sulphur. This substance is readily soluble in bisulphide of carbon, out of which it crystallizes in the rhombic form. If the process of crystallization be followed under the microscope, nothing definite as to the nature of crystalline growth can be made out. The first objects which appear are definite crystals, and these grow by accretion. If, however, the solution of sulphur be thickened with Canada balsam then, provided the proper proportions of the different substances have been employed, some very interesting phenomena may be ob-

served by the aid of the microscope as the bisulphide of carbon evaporates. Minute fluid spheres arise in the medium and grow by mutual absorption. They finally consolidate as clear, transparent, isotropic bodies, and to them Vogelsang has applied the term globulites. It is impossible to determine absolutely the composition of these globulites, but there seems no reason to doubt the conclusion of Vogelsang that they are portions of the Canada balsam which are richer in sulphur than the surrounding mass, and that they arise in consequence of the attempt of sulphur to crystallize under unfavorable circumstances. Similar bodies may be observed in certain rocks, slags, and blow-pipe beads, although the crystallizing compounds must be very different in the different cases.

Under certain circumstances the mass of sulphur and Canada balsam solidifies with the formation of globulites, but under other circumstances additional phenomena may be observed. When the resistance of the medium is too great to prevent the union of the globulites, but not too great to prevent their approach, they become united into various more or less definite forms. The mode of union depends partly on the way in which the globulites attract each other, and partly on the movements in the mass. A linear arrangement of the glubulites is very common, and to the form arising in this way Vogelsang has given the name margarite. A rectangular grouping is also not uncommon. From a study of the various forms arising in consequence of the union of globulites, Vogelsang concludes that in the case of sulphur there are in each globulite, as it were, three directions at right angles to each other, in which the attraction is considerable, and that in one of these the attraction is decidedly greater than in the other two.

The building up of the compound forms naturally leaves the surrounding space free from globulites.

Under certain circumstances the globulites become fused, as it were, at the points of contact. This occurs when the resistance is sufficient to prevent the assumption of the spherical form, but not sufficient to resist the destruction of the pellicle at the point of contact. In this way rod-like bodies, termed longulites, arise.

It must be remembered that all these forms are strictly isotropic. They are not, therefore, in any sense of the word, crystals. The moment a true crystal of sulphur appears, it can be recognized by its doubly refracting properties. They have been termed crystallites, wherever they occur, by Vogelsang, and they evidently arise in consequence of the attempts of some definite chemical compound to crystallize under conditions which do not admit of the free approach of the molecules.

Between crystallites and perfect crystals showing definite external faces there are numerous intermediate forms, such as microlites and skeleton crystals. As further illustrations of the influence of the environment we have only to consider the facts that no two crystals of the same substance are precisely alike in all their characters, and that some substances, like sulphur and carbonate of lime, may be made to crystallize in two different systems by varying the conditions under which the crystallization is effected.

There can be no doubt, then, that two factors are involved in the determination of the properties which crystals present: the inherent forces of the crystallizing substance and the influence of surrounding substances.

So far, we have referred only to the birth and growth of crystals. But the history of a crystal does not cease with its formation. With a change in the surrounding circumstances the crystal may be modified or destroyed. Thus we see that crystals have a kind of life-history; they are born, they grow in size by accretion, and finally they cease to exist as distinct individuals.

As an illustration of the influence of a change of physical condition on the character of a crystal, consider the case of leucite. At ordinary temperature this mineral is generally regarded as tetragonal, and it certainly shows double refraction in thin sections. Klein has shown that by heating leucite to a point far short of its fusibility it may be rendered perfectly isotropic, and hence follows the conclusion that leucite is really isotropic when subject to the conditions under which it is formed. That crystals should be in a state of stable equilibrium, so far as molecular forces are concerned, when subject to the physical conditions under

which they are formed, is exactly what we should expect, and that this equilibrium should be disturbed by a change in these conditions is also very easy to understand.

As further illustrations of the principle here referred to, consider the various cases of paramorphosis, such as the change from arragonite to calcite, or from calcite to arragonite; or, again, the corresponding changes in sulphur.

Illustrations of the changes which arise in crystals in consequence of changes in the chemical conditions to which they are subjected, need not here be referred to in detail; the destruction of crystalline rocks by denudation is, of course, a consequence of these changes.

Consider, now, the rocks of which the earth's crust is composed. They also have a life-history. They are formed and destroyed, and it is the business of the petrographer not only to describe and classify them, but also to trace out the cycle of change. For the purpose of illustrating this branch of petrography let us consider certain facts with reference to the genesis of crystalline igneous rocks. It will be admitted on all hands that such rocks as granite, syenite, diabase, rhyolite, trachyte, andesite, and basalt have originated by the consolidation of an intensely heated silicate magma under different conditions as to temperature and pressure. The consolidation has been accompanied—except in those cases where the magma has consolidated as a homogeneous glass, and these will be left out of account for the present—by the development of crystals. If, then, we would understand the manner in which crystalline igneous rocks have been formed, we must consider the subject of crystallogenesis in silicate-magmas. Numberless facts which need not here be referred to prove that the process of consolidation is not a sudden one. As the surrounding circumstances (environment) become more and more favorable to crystallization, the minerals separate out one after the other, and at last the whole mass becomes solid, and the rock is formed. The temperature at which any given mineral forms is not determined by its own fusibility. The laws of the formation of minerals in igneous rocks are analogous to those which determine the formation of salts from concentrated aqueous solutions. Cooling influences the separation of the different minerals only in so far as it affects the solubility of the constituents of the minerals in the silicate-magma. The point at which a mineral forms from a silicate solution has, then, no more connection with its fusibility than the point at which graphite forms in molten iron has with *its* fusibility.

Another point of very great importance is this—the differentiation of crystals in an originally homogeneous magma must necessarily be accompanied by a variation in the composition of that magma. It becomes, then, of great interest to determine the general order of the formation of crystals in igneous magmas. On this subject we have a most valuable and suggestive paper by Rosenbusch, entitled "Ueber das Wesen der körnigen und porphyrischen Structur bei Massengesteinen" (*Neues Jahrbuch*, 1882, ii., p. 1). Before proceeding to give an account of the portion of this paper which bears more particularly on the subject we are now discussing, it may be well to call attention to the methods available for the purpose of determining the order of the formation of the minerals in a rock. There are two. In the first place we may observe the phenomena of inclusions, and in the second place we may observe the extent to which crystalline form has been developed. If one mineral is seen to be included in another, then we may safely infer, subject to certain precautions, that the included mineral is the earlier of the two, and if one mineral shows a more perfect form than another with which it is associated, then we may infer—again subject to certain precautions—that the mineral with the more perfect form is the earlier.

Now, in the paper above referred to, Rosenbusch divides the constituents of igneous rocks into four groups:

(1) The ores and accessory constituents (magnetite, hematite, ilmenite, apatite, zircon, spinel, sphene).

(2) The ferro-magnesian silicates (biotite, amphibole, pyroxene, olivine).

(3) The felspathic constituents (felspar, nepheline, leucite, melilite, sodalite, haüyn.

(4) Free quartz.

He then calls attention to the contrast which is presented by the granites and syenites on the one hand, and the diabases

on the other. In the former the following law is adhered to with a very great amount of persistence: The order of formation is that of increasing basicity; the ores and accessory constituents are first formed, and the quartz is the final product of consolidation. In the diabases and gabros there is apparently an exception to this law of increasing basicity, the augite consolidating after the felspar. Rosenbusch proposes to divide the granular holo-crystalline rocks into two classes: (1) Those in which the minerals of the second group in the above classification consolidate before those of the third, and (2) those in which the reverse relation holds. He then calls attention to cases illustrative of the law of increasing basicity which are furnished by the order of separation in the individual groups. Thus, in the ferro-magnesian group, olivine is older than biotite, amphibole and pyroxene; and biotite is older than the bisilicates. In the felspathic group, triclinic felspars are older than monoclinic [there are exceptions to this rule, as, for instance, in the porphyroid of Mairus in the Ardennes, where orthoclase crystals are seen to be surrounded by a narrow zone of oligoclase], and the basic triclinic felspars are older than those which contain a large percentage of silica.

The views of Rosenbusch are based on the assumption that the order of formation of crystals in igneous magmas is determined solely by chemical conditions. That these conditions are the more potent seems quite clear, but there are facts which appear to show that physical conditions are not altogether without influence on the result.

The law of increasing basicity may be accepted without hesitation as expressing in a general way the truth as regards the order of separation of the different constituents of igneous rocks.

Now, a very interesting conclusion follows as a natural consequence of this law. The effect of progressive crystallization in a magma must be to increase the percentage of silica, to decrease the amount of lime, iron, and magnesia, to increase the total amount of alkalies, and to increase the potash relatively to the soda in the part which remains liquid. It is always satisfactory to find independent evidence confirmatory of any conclusion at which one may have arrived. Now, I think we have confirmatory evidence of this kind in the present case. It will be admitted on all hands that the crystals in porphyritic rocks, such as hypersthene-andesite, have been formed in a magma, the composition of which is represented by the bulk analysis of the rock. If, then, we compare the bulk analysis with the analysis of the ground-mass deprived of its crystals, we ought to find confirmation of the above conclusion.

Dr. Petersen has isolated and analyzed the ground-masses of two of the Cheviot porphyritic rocks, and by comparing these with the bulk analysis of the rock, the truth of the conclusion is most strikingly illustrated. The effect of progressive crystallization in the andesitic magma has led unquestionably to an increase in the amount of silica, a decrease in the amount of lime, iron, and magnesia, an increase in the amount of alkalies generally, and an increase in the potash relatively to the soda. In the rock itself, soda is in excess of potash; in the ground-mass, potash is in excess of soda.

There is yet another piece of independent confirmatory evidence. Every geologist is familiar with the phenomenon of contemporaneous veins. The general view held with regard to them is that they represent portions of material which remained fluid after consolidation had progressed to a considerable extent. If this view be correct, then they should hold the same chemical relation to the main mass of the rock as the ground mass of the Cheviot andesite does to the main mass of the andesite. Mr. Waller has recently analyzed certain contemporaneous veins which occur in the bronzite diabase of the Penmænmawr. He finds that they contain about 7 per cent. more silica than the normal rock, less lime and magnesia, more alkalies, and more potash than soda, although in the normal rock soda is in excess. Contemporaneous veins in the Rowley rag dolerite have also been investigated by Mr. Waller, with the same result as far as increase in silica and total alkalies is concerned. The relation of potash to soda has not yet been determined.

I believe it is admitted to be a general rule that contemporaneous veins con-

tain more silica than the rock with which they are associated. It will be seen that there is abundant evidence of an independent character to confirm the general truth of the conclusion which follows from a consideration of the facts brought forward by Rosenbusch.

I should not have treated this subject at such length did it not appear to have an important bearing on the origin and sequence of volcanic rocks. I can best explain this by referring to the Cheviot district, with which I am slightly acquainted.

Andesitic lavas and tuffs cover large tracts of this district. These are unquestionably the products of surface volcanic action. In the central portion of the volcanic area there is a mass of augitic granite. A consideration of the mineralogical composition of this granite shows that it cannot belong to the acid group of rocks, and this conclusion is confirmed by an examination of the chemical composition of allied rocks from the Vosges. So far as we can judge, in the absence of analyses, there appears to be a very close connection beween the composition of the plutonic and that of the volcanic rocks of the Cheviot district, and we therefore seem justified in concluding that the plutonic masses differ in character from the andesitic lavas merely in consequence of difference in the conditions of consolidation. The plutonic rocks represent the consolidation of the andesitic magma beneath the surface, and therefore under great pressure; the lavas and tuffs represent the consolidation of the same magma at the surface.

I now come to the point to which I wish to direct special attention. The andesitic lavas and tuffs are traversed by quartz-felsite dykes in such a way as to show that a magma of rhyolitic composition must have been erupted by the Cheviot volcanoes subsequently to the period characterized by the eruption of the andesitic magma. Contemporaneous veins, similar in character to the quartz felsite dykes also occur in the plutonic rocks. Again an analysis of one of the quartz-felsite dykes by Mr. Waller agrees almost exactly with the analysis of the ground-mass of the hypersthene-andesite by Dr. Petersen.

Putting all these facts together, we conclude that the eruption of an andesitic magma was followed, in the history of the Cheviot volcanos, by that of a rhyolitic magma in consequence of progressive crystallization in the deep-seated plutonic source. The rhyolitic magma is, so to speak, the mother liquor out of which various basic minerals have crystallized. Suppose a half consolidated plutonic mass, originally of andesitic composition, to become subjected to a powerful crush, such as that which unquestionably arises in the earth's crust under certain circumstances. The mother liquor will be squeezed out of the mass, like whey out of cheese, and it may finally consolidate as contemporaneous veins in the plutonic rock, as dykes in the surrounding volcanic rocks, or as rhyolitic lavas and tuffs at the surface. The ideas here thrown out appear to me to be capable of extension to other volcanic regions; but as the sequence in these regions is generally complicated by the coming in of basic rocks during the latter phases of volcanic activity, it will not be advisable to enter more fully into the subject on the present occasion.

The special characters which igneous rocks present, then, are to be traced to the chemical and physical properties of the original magma, and to the influence of surrounding circumstances. Rocks, like minerals, are in a state of stable equilibrium when subjected to the conditions of their formation. When subjected to other conditions, whether physical or chemical, they usually undergo a change. The destruction and disintegration of igneous rocks by the various agents of denudation are familiar to every student of geology, and need not therefore be described on the present occasion.

I trust I have now said sufficient to show that the science of petography is one of the greatest importance to the geologist of the present day. The remarks on ætiological petrography are, of course, only intended to illustrate the nature of this branch of the subject, and to show that conclusions of the greatest theoretical interest may be expected to follow from a careful consideration of the facts acquired by work in the other branch of the science.

OPTICAL REFINEMENTS IN ARCHITECTURE.

From "The Building News."

THE Greeks and Romans had a keener sense of the apparent weakness of certain lines in architecture than have modern artists. We all know, on the authority of Vitruvius, but more particularly from the careful investigations made by Mr. F. C. Penrose, M. A., into the refinements of Greek architecture, what attention was paid by the Greek architects of the time of Pericles to the proportions and lines of their edifices. Their extremely sensitive and educated eyes perceived various objectionable effects in the horizontal and vertical lines of their buildings. Thus the effects of straight lines in the entablatures and steps of their temples, and of the uncorrected axes of their columns, especially those at the angle, were early noticed, and in the Parthenon we find a decided curvature of the one and a considerable declination from the perpendicular of the other. Thus Mr. Penrose discovered that in each front and flank of that great temple all the axes of the columns were parallel to each other, except the axes of the angle columns, where the inclination on both fronts is found to be 1 in 106. The object of this inclination inwards in the angle columns is obvious; it was to correct the ocular impression of the portico spreading out at the top, just for the same reason that the *entasis* of a column was given to correct the impression of concavity in the sides, or the convexity of horizontal lines was given to make them appear to the eye perfectly level instead of deflecting towards the center. Vitruvius refers to these illusions, such as the unpleasant effect produced on the horizontal cornice by the raking lines of the pediment; and there is a treatise on optics, written by Heliodorus, which proves beyond question that architects in his day studied optical illusions, for he says: "The business of the architect is to make his work harmonize with appearances, and when anything tends to be misrepresented to the eye he must find contrivances to guard against it, providing for the apparent, and not for the real, equality and symmetry." As Mr. Penrose's results are published, it is unnecessary here to dwell at any length on them. He has proved beyond doubt that the horizontal lines of the Parthenon are curved to a perceptible degree, that the lines of the front are lifted more than those of the flanks—namely, .228 on the steps and .171 on the entablature, represented by the fractions $\frac{1}{440}$ and $\frac{1}{600}$ respectively; while in the flanks they are lifted .340 and .306 or about $\frac{1}{290}$ and $\frac{1}{330}$ respectively. Mr. John Pennethorne first pointed out the curvature in horizontal lines of Greek buildings nearly 50 years ago, and Mr. Watkiss Lloyd, who has devoted considerable study to the subject, has also pointed to certain harmonies of proportion in Greek architecture, upon which basis all buildings were designed. Mr. Lloyd's theory is that a leading proportion was first chosen for the principal components or the length of the upper step of the temple measured in front and flank, which in the Parthenon has the ratio of 4 to 9, the other parts being regulated by a series in which in every term the numerator and denominator differ by the same number as they do in 4 to 9. In other words, as Mr. Lloyd says, the parts were proportioned to one another by simple ratios by building up from the whole to a part, and from one part to another with which it had organic dependence. Thus, the proportions of the temple were adjusted to certain ratios. Taking the angle columns, their size was determined by making the abacus one-fifth of the height of the column; the distribution of the columns was eustyle, or in the proportion of 4 to 9, while the diameter of columns and other parts were determined by the application of similar ratios. Again, the term $\frac{7}{12}$ gave the height from step to apex of cymatium. In one great modern building of glass and iron, the Crystal Palace, a unit of 8ft. governs the plan, every horizontal measurement being a multiple of 8ft. The effect is certainly agreeable. Perhaps few architects would care to follow such analogies in the proportions of modern buildings, though

they are worth a careful study. Optical refinements are, however, useful, and means of correcting the illusions caused by horizontal members, straight lines, and the connection of oblique to perpendicular lines, ought to be devised in all important buildings. Even in such practical matters as the finishings of rooms, the effect of cornices ought to be considered. In "Wightwick's Hints," the effect produced by a heavy cornice, in making a room of given height and size appear low, is pointed out by diagrams. If height is desired, the cornice is better placed chiefly or wholly in the ceiling; if lowness, then on the wall. The intervention of a coye may be found useful in modifying the apparent height of a room or a corridor, and in such a manner the architect can diminish the apparent height of the inclosed space. Upon an analogous principle the eye estimates a dimension, say a height, by any easily-perceived unit, such as the courses of brick or stonework, the joints forming a kind of scale by which the eye judges the height, on the same principle that a figure near a building becomes a measuring unit. To the architect the value of a scale is all important, as he can by its means impress the beholder with the magnitude of his work. The measuring unit of the human figure has at all times served this purpose. Those who have visited St. Peter's at Rome can only realize the vastness of its dimensions by this means, as the proportions of the sculpture serve to reduce its real size, a fault which it has in common with many edifices in which single orders of columns are employed. We here see the value of a proper scale of details. If apparent size is required, it is easy for the architect to proportion his details to that end. He can reduce the size of his cornice or increase the number of members, and subdivide his lengths by pilasters or pillars, or by arbitrary divisions of the wall-space, or his heights in the same manner by the superimposition of orders, or the division into parts by string courses or stories. In surface decoration scale can be readily obtained by the selection of a proper design or a pattern, for the greater the subdivision, or the smaller the pattern, the larger the space becomes, as everyone knows who has tried the effect of different wallpapers. These are well-understood matters on which we need not dwell any longer. Our object is to point out a few less-understood and more recondite sources of delusion of a purely optical kind.

The apparent weakness of a straight lintel or a large square-headed opening may not affect much our sense of beauty in small apertures such as windows, though in the case of a long lintel or a girder the effect on the eye is disagreeable. The long straight tie-beams of roofs, whether of wood or iron, produce a weak effect; they invariably appear deflected instead of straight to the eye. Few architects, however, trouble themselves about the matter, or care to apply any curve, such as the catenary, to make the correction, and the same may be said with regard to the application of curvature to the bounding lines of columns and spires, which is not often made, though very easy. The Greeks used an arc of one of the conic sections for the purpose. Mr. Penrose says the hyperbola was chosen for the entasis of the columns of the Parthenon because that curve offers considerable variety of curvature in so slight an arc, the deflection of which did not exceed one six-hundredth part of the length of the column. We all know that the conic sections were used in the mouldings, as in the corona of the cornice. One cause assigned for the weakness apparent in straight-lined and perpendicular columns, due to their apparent spreading outwards when viewed in front, is that of irradiation, an optical principle which causes an object to seem to spread by the light cast upon it. Thus the columns of the Parthenon were exposed to a strong light on their upper part, which were seen against a shaded background, the result being to make them appear expanded at the top, and to give, in a straight-lined column, an attenuated or concave effect in the central portion of the shaft. The inclination given to the axes of the angle columns before alluded to, the diminution of the columns, as well as their entasis or curvature, were all expedients more or less intended to correct the illusive effects due to the sudden contrast in direction of lines and irradiation of light.

Let us see how the same principles of correction may be applied to features and

details of buildings of the present day, taking the case of uncorrected horizontal and vertical lines, especially such as are in juxtaposition or combined with other lines. A gable or pediment furnishes a good instance of the effect upon a horizontal line of the raking cornices which spring from the ends. The cornice in such a feature always looks sunken in the center, the opposition of the oblique lines of pediment helping to aggravate the appearance of deflection. A like effect happens if the pediment, instead of being straight sided, is curved. This sunken appearance is evidently greater than would have been if no such upper contrasting lines were visible. Here we have a very obvious case of the illusion caused by contrast of lines having different degrees of inclination. The raking cornices on the same principle appear to drop in the centers of their length. A very noticeable instance of contrast or opposition of lines is observed when an arch, especially of flat curve, springs from or abuts upon vertical piers or walls, as when we see a segmental or obtuse pointed arch abutting against side piers. The latter appear to be thrown out of the perpendicular or to spread at the top. Many of the chancel arches of churches illustrate in a remarkable manner the illusive effect here mentioned. The lofty central piers of most cathedrals, which carry the tower, look to diverge from the vertical at the springing of the arch; the obtuser the latter is, the more divergent the pier lines become. Now, there is a good reason for a correction to the piers to counteract this effect; even an inch or two on each side would correct the visible distortion due to the contrast of lines. Many arches look weak from this cause; the more abrupt the angle between the arch curve and the vertical line, the greater the distortion. A more remarkable illustration of the illusion caused by opposing lines may be observed when two arches at different levels spring from the same pier, as in the case of a chancel or tower arch over the nave and a lower aisle arch. The optical effect produced is to make the pier look crooked. At the junction of the lower arch there is a perceptible curvature of the pier inwards, the lines of the two arches on different levels making the pier bend inwards in the center and outwards at the top, producing a crippled effect. In an arcade of equal and level arches the effect is counterbalanced and neutralized. Other instances often occur showing the influence of contrast, as when a level string course in passing over an arch causes the horizontal line to bend, apparently—a similar effect to the raking and horizontal lines of a pediment. In these cases there is a strong reason for applying a correction to the straight lines. Flat surfaces suffer from a similar sagging when in juxtaposition to contrasting lines or surfaces. Thus a flat ceiling, having a sharply curved cove, invariably appears to bend downwards, the rounded corners of a room make the straight sides, especially at the cornice, look distorted at the meeting of the curve and straight line. A little easing at the junction would be sufficient to counteract the unpleasing crippled effect at these points. Different degrees of illumination on a surface, as we have already remarked, is a cause of distortion, and may tend to increase the illusion of contrasting lines and surfaces. The drops under the tænia are made conical to counteract the apparent diminution caused by their ends being seen against a bright surface, the effect of light being to reduce their width, as when a column is seen against a shaded background at the top. From what we have said the reader will see the importance of attention to details and outlines, differently juxtaposed and illuminated. Contrast, as we have shown, tends to increase the difference between things. The difference of direction between two lines, as in those forming an angle, always appears greater than it is. Contrasts of light and shade, and of color, exhibit the same law, as shadow always makes the luminous object appear the brighter, and light the shadow the deeper. Green emphasizes red, which appears redder by the contrast, and so of all contrasting colors, shades and tints.

What has been observed with respect to right lines applies with equal force to curves. Thus æsthetically we have a preference for curves of contrary flexure to those which are of unvarying curvature, such as circular ones. The conic sections are more interesting than those formed of circular arcs, because of their varying degrees of curvature. But the

principle of contrast has something to do with the preference. Hogarth's "line of beauty" is a curve of contrary flexure—that is to say, the two curves forming it are in opposite directions, one is counteracted by the other, and a highly agreeable curve is the result. Let us suppose a curve joined to a straight line, the effect is displeasing; a distorted appearance at the junction is the result, and this is more aggravated as the curvature is sudden. Thus in a flattened Gothic arch, such as the Tudor, where the upper arcs are too straight, a crippled effect invariably occurs; the upper portion of the arch appears to sink at the haunches where the lower and upper segments unite.

When a perfectly straight line is substituted with a sharp curve at the springing, examples of which are not uncommon, the illusion of depression becomes very marked and disagreeable to the eye. We have here a good lesson of the value of studying ocular impressions, of easing the union between curves of different degrees of convexity, or of arcs of different radii, for when the difference is great, a disagreeable effect is sure to be the result. Architects, in drawing arches of four centers, or in designing window tracery, are not often sufficiently careful; the selection of a curve to please the eye is not so much a question with them as a convenient center or length of radius. Our observations on curvilinear forms might be extended indefinitely. The subject is exhaustless, and has not been adequately dealt with by writers upon architecture. Luckily, nature supplies a corrective to lines of unvarying curvature. In perspective the circle becomes an ellipse; and as we view it in different directions, so the curvature is ever changing with the eye from the elliptical to the hyperbolic. Through this beneficent law of perspective the circle is never seen in but one position; so the vaults and domes of our buildings present ever varying lines, and become a charm to the eye. In these cases the effects produced are more æsthetic than optical, though they equally arise from the pleasure we experience in tracing curved lines, which are less tiring to the muscles and nerves of the eye than those of right lines and angles.

The laws of perspective not only produce a charming variety in curves, but apply a corrective to straight lines and the boundaries of objects viewed by the eye. Although we design in elevation we see in perspective. Those who have studied the principles of binocular vision know that all right lines appear curved when we stand in the center of a front of a long building. The summits or cornice lines, if level, drop down on each side to the points of distance or the vanishing points of the picture, so the same holds good of planes above or below the level of our eye; or, in other words, all planes parallel to the horizontal or vanishing plane at the level of the eye will, when extende , approach the latter. The higher the plane is above our heads the more concave it will appear. These planes, by a natural law, regulate the solid appearances of all objects. Now, the law we have referred to offers another reason for making our straight level lines convex; and though it is perfectly true that this law of perspective applies its own remedy to our right lines and planes, we have still to make compensation for the effects produced by contrasting perpendicular and inclined lines, like those of the angles of buildings and of raking pediments. In short, we never see right lines straight any more than we can see a circle in perspective. These are truths which appear as mathematical truisms, but they are constantly and oddly overlooked by designers. Nature, as she "abhors a vacuum," equally abhors a straight line and a level plane. They are mathematical abstractions which never enter into our views of natural objects. We may look at an extended facade from a distance from a central point of view, but its lines and features grow gradually smaller and dimmer as they recede on either side of us. We cast our eyes upward at a lofty tower whose sides are parallel; but their parallelism vanishes, and we see the tower ascending, but lessening in bulk—bounded, in fact, by lines which, according to nature's own perspective, are gentle and imperceptible curves; so that, if we would follow nature, we should apply an analogous law to our lines whenever they appear weak or unite harshly.

THE SCIENCE OF MECHANICS AS APPLIED TO THE FINE ARTS.

By GEORGE SIMONDS.

Papers of the Civil and Mechanical Engineers.

I have often been asked how it happens that I, who am an artist, am at the same time occupied with mechanical pursuits, and whether there is not some incongruity in the union of the two professions.

To this I reply, that whilst I am before all else an artist, I have nevertheless remarked that art without a sufficient knowledge of mechanics is weak and helpless; and that, on the other hand, it has in all ages reached the highest perfection in the hands of those artists who have possessed the greatest mechanical knowledge.

To convince ourselves thoroughly of this fact, we need only to glance at the artistic achievements of savages in the present day, of whom we can with certainty say, that they have very small mechanical knowledge.

We find that their decorative art is either confined to very simple geometric patterns, or if it aspires to represent living forms is not able to rise above the grotesque; whilst architecture amongst them is confined to the construction of huts or wigwams.

Architecture, of course, more than the two sister, or daughter, arts, as they should more properly be called, is dependent for its development on mechanical science. This fact is so evident that it is needless further to insist on it. We do not expect a savage people to have any architecture. It is on this account that we are so astonished by the ancient monuments found in various parts of the world, such as rocking stones, druidical remains &c.; and yet these do not really prove any great mechanical knowledge, but are monuments of patient labor, aided only by the most simple appliances, and cannot, save by courtesy, be considered as architecture.

Painting and sculpture can only find proper development amongst nations who have arrived at some knowledge of mechanical science, because unless we have architecture of some pretension beyond that of a mere shelter from the weather, we have no need of, and indeed no place for the decorative arts.

In the infancy of the human race, the mere struggle for existence would preclude any attempt at art. Man's needs had to be satisfied before he had leisure to think of aught else. Food, shelter and clothing would occupy all his time and all his energy. To obtain the first he would require a tool to dig the ground, a weapon to kill his prey. For shelter a cave would suffice, and for clothing, the skins of the beasts he had killed.

But as man by practice became more skillful in finding his food, he would have more time on his hands, and be able to consider the means of providing himself with a more suitable and convenient residence. Thus the hut or wigwam would be invented, and being enabled to place his domicile in the locality best suited to supply his material wants, he would again find himself with time to spare. This would be employed in perfecting and embellishing the implements and utensils of which he was already possessed, and also in improving his own personal appearance. As the hut or wigwam would be his first architectural effort, so his first attempt at painting would probably be to daub his own skin with some pigment to render him either attractive to his friends, or terrible to his enemies; whilst his sculpture would consist of rude patterns incised on the handles of his tools or weapons.

The discovery of the plastic properties of clay, and subsequently of the art of pottery, would give an enormous development to the arts of Sculpture and Painting, especially after the invention of the potter's wheel, which was doubtless one of the most ancient if not actually the first mechanical appliance used in connecnection with the fine arts.

To appreciate the immense value of this contrivance to the artists of far-off ages we need only visit the British Museum, where we find vases, cups, bottles and all kinds of earthenware goods which were

evidently spun upon the potter's wheel and afterwards profusely decorated, not merely with conventional patterns, but with figures and groups of men and animals, sometimes colored, but more frequently in red on black ground, or black on red. The Etruscans and Greeks particularly excelled in the production of these pots and vases, which in their hands became valuable works of art, models of style both in drawing and in composition to the artists of all ages.

It was not, however, in the earliest ages that this was the case; on the contrary, the earliest examples of vase painting are, as we should naturally expect, rude and lacking in correctness of proportion and of outline.

The Egyptians seem to have been the first to recognize the importance of regulating the fine arts on scientific and mechanical principles. In the earliest stages of Egyptian art, this does not seem to have been the case, and the oldest work of art we know, a wooden portrait statue in the Museum at Boulak, is thoroughly unconventional, not to say naturalistic in treatment. Doubtless, however, it was found that the absence of school or tradition led to extravagances, and it became needful to lay down fixed mechanical rules for the guidance of artists. As all the science and mechanical knowledge of Egypt was vested in the priesthood, it was they who laid down the rules of construction, proportion, and composition which governed the arts in that country. Little has come down to us of what those laws were, nevertheless, there have been found incompleted works mapped out according to a particular scale or Norma.

The one idea which was ever present to the Egyptian mind seems to have been Eternity. This they strove to express in all their works of art, sculptural as well as architectural, by their leading qualities, stability and durability.

These qualities they insured by making their monuments of vast size, and of the hardest and most lasting materials, as well as by the solidity and compactness of the general design.

The erection of Pyramids and Obelisks by a people who had neither steam power nor hydraulic machinery at their command, excites our just admiration; but although it argues a certain mechanical knowledge, it does not prove an acquaintance with more than the simplest mechanical appliances, set in motion by a boundless supply of brute force. I do not therefore insist on these works, wonderful as they are, as showing any great influence of mechanical science upon art; but with Egyptian sculpture the case is different, and I would submit that without mathematical and mechanical knowledge of a high order, it would have been quite impossible for any people to have erected such colossal works as the Sphynx, the Memnon, and many others. The methods employed by them for working the hardest and most intractable materials have been, and to a great extent are still, matters of conjecture; although it has recently been discovered that for certain purposes they made use of a tool, in its action exactly resembling a modern diamond rock drill. To me, however, it seems less wonderful that they should have been able to master the hard material, than that they should have succeeded in giving pleasing expression and accurate proportions to works of such vast size. It is evident that they must have been hewn out by the united action of many men working at once; no one man could have achieved such a task. There must, therefore, have been a design for them to work to. And to produce a satisfactory result mathematical principles must have been skillfully applied to the enlargement of the small model.

In the British Museum there is a small stone lion of Egyptian origin marked over with lines intersecting each other at various angles, which I think was in all probability a small model from which to construct a similar lion of much greater dimensions.

The art of Egypt probably derived, for a time at least, great benefit from the rules and restrictions imposed on it by the priesthood; nevertheless the system must have had its drawbacks, for if it prevented extravagance and absurdity, it also effectually precluded progress even of a legitimate kind. The same observations apply with equal force to Assyrian art, from which, but for such restrictions, as great results might have been expected as were afterwards obtained in Greece.

With the Greeks the case was of course

very different. It is true that they derived their knowledge of the arts and sciences from Egypt, but they had not the same religion, and not being governed by a priesthood they had no reason for observing the rules and traditions of Egyptian art for one moment longer than they found it convenient to do so. Thus we find that even in the early days of Greek art, when its character is quite archaic, the figures are full of movement and energy, and before long the faces only seemed to retain traces of Egyptian influence, as, for instance, in the Ægina Marbles now in the Museum at Munich, which, although carved only about 40 years before the time of Phidias, when Greek art suddenly rose to its highest, nevertheless, in some little peculiarities of form and feature show their Egyptian descent.

Amongst the Greeks about this time, art and science seem to have made most rapid progress; and sculpture and architecture must have received great assistance from the schools of Euclid and other mathematicians of that day, whose teaching would be invaluable to an artist, in assisting him to understand the laws governing the construction, movements, and balance of so complicated a piece of mechanism as the human form. And it needs, I think, little argument to show that, other things being equal, the man who will make the best machine drawing is he who best understands the machine it represents. So it is with the representation of the human figure, more especially in sculpture, for in painting, color and chiaroscuro are like charity, which often covers a multitude of sins. In sculpture, however, color cannot be made to gloss over faulty and unmechanical construction; and though many sculptors at the present day, of the so-called naturalistic school, endeavor to give an air of reality to their works by imitating the texture of the skin, and other minute details, they often grossly neglect the correct mechanical construction of their figures, so that even if they were suddenly to come to life they could not move, their machinery being ill-designed and badly fitted, even though to the unmechanical eye it may look well enough and be very highly finished.

Construction, movement and balance, the three great points to be observed in the artistic representation of living forms, are all dependent on definite mechanical laws; and we have abundant proof that the Greeks were quite alive to this fact, and closely studied the laws that led in their case to such brilliant results.

Unfortunately, but little has come down to us of the formula they used. Something, however, we have; not much, indeed, but just enough to show us how much we have lost. I refer to the Norma or Canon set forth by the sculptor Polycletes, a very defective account of which has been handed down to us by Vitruvius, who himself does not seem to have been very clear about it.

In the early part of the Christian era, both art and science fell to a very low ebb. Art, indeed, was so poor that when the Romans wished to build a triumphal arch in honor of Constantine, they were obliged to despoil other pre-existing monuments in order to adorn the arch with sculptures which they had not the skill to execute themselves.

It was not until the revival of art and science in the middle ages that we have anything of note to record; but in the 14th and succeeding centuries we are met with a multitude of names of highest fame. In those days we find men who were like Leonardo da Vinci, engineers, both civil and mechanical, as well as sculptors, painters, architects, and who yet found time for the study of poetry, music and astronomy.

Previously to this great revival, the mechanical process of art had been utterly lost; and even at the present day we know but little of the systems whereby the ancients produced their masterpieces. Curiously enough, we have but few unfinished works of antiquity, and these few throw very little light on the system of measurement they employed. We know indeed from the many works in terra-cotta that have survived, that they were skillful modelers, and we know also that they were acquainted with the properties of plaster of Paris, as it is commonly called, and that they were skilful moulders, but we do not know how they reproduced in marble the forms they had designed in plastic material; we do not know whether they were in the habit of making full-sized models of their statues and copying them in marble, or whether

they usually made small sketches in clay or plaster, and enlarged from these. As far as their tools are concerned, we know from the marks that they have left that they were almost identical with those that are in use to-day. They used a point tool for roughing down, which was simply a piece of rod drawn down to a square point, with which they wedged off lumps of marble with a hammer. Having reduced the block to a rough shape, they then brought it still nearer to size with a flat chisel, the edge of which was serrated; and the work was finished with ordinary chisels of various sizes, and with rasps. All these tools were doubtless precisely the same as those used in the middle ages, and at the present day. They also used a drill for removing marble in the undercutting of draperies, and in other parts where it would have been difficult or dangerous to use the hammer and chisel. There is nothing to show how the motive power was applied to these drills, but there is at least a probability that it was a reciprocating motion produced by a cord, wound round the shaft of the drill, and kept tight by a bow, and worked by the carver himself; or else the two ends of the cord may have been worked by an assistant, whilst the carver guided the drill. This latter is the method usually employed in Italy at the present day, as it leaves more freedom to the carver than when the bow is used. Having both hands at liberty, the carver can use his drill as a slotting tool, cutting curves as easily as straight lines. I have, however, never seen any evidence that the ancients were in the habit of so using this tool; on the contrary, wherever I have seen the drill marks they have been clear, distinctly separate marks, with no indication whatever of a side traverse. In the middle ages they do not seem at first to have had any very clear system either of proportion or of measurement, and the mechanism of the human figure was very imperfectly understood. As a natural consequence the figures produced at that time were grotesque, not to say incorrect in action, poor in form and bad in their proportions. As, however, the laws of mechanics were more studied, and the art of construction was so well understood that it became possible to erect such structures as the bell tower of Giotto and later Bruneleschian Dome, the art of sculpture made corresponding strides. The discovery of fragments of antique art gave an impetus to the study of the beautiful, and the proportions of the figure were reduced to a truer standard, whilst the study of anatomy, although not permitted, was ardently practiced by some few artists, and resulted in correct mechanical construction and harmonious movement. The parade of anatomical knowledge has often been made a reproach to Michael Angelo by those who were too ignorant to understand him; and indeed to a superficial observer there would seem to be some reason for censure. Yet there is not one of his figures that is not full of life and energy. The carving is often very rough, the figures are rarely, if if ever, finished in all parts, but one feels that the mechanical construction of the figure is correct. It may be exaggerated, the man may be a man of forty horse-power, but nevertheless he is a man with limbs and joints of a man, correctly articulated, with possible, not impossible muscles and tendons—muscles which need only the vital spark to contract and set the limbs in motion. These figures possess in an eminent degree that highest of artistic qualities, potentiality of motion.

The accounts we have of Michael Angelo's method of working are not as ample as we could desire. We have, however, a diagram from his own hand for calculating the proportions of the human figure, and we have in the writings of Benvenuto Cellini, who was himself acquainted with the great master, what professes to be an account of his system. We have also a vast number of small models and studies in wax and in terra-cotta for large statues, but we have no full-sized models; from which we may, I think, conclude that he made small-sized models when the work was to be executed in marble, and full-sized ones only when it was to be cast in bronze when, as the "cire perdue," or lost wax system of casting was the one he employed, the model would be destroyed in the process. According to Cellini, his plan was to sketch with charcoal on one side of the block the outline of the figure he wished to carve, and that then he at once attacked the block, and, working always from the same side, produced the figure first as a low relief, then in ever-increas-

ing relief, until it stood out freely in the round. To any one who knows the practical difficulties of sculpture this sounds very wonderful, and although I am far from saying that it is impossible, yet knowing Cellini's love for the marvelous, and his hero worship of Michael Angelo, I am inclined to take this account with some reservation. That Michael Angelo could carve a statue without mechanical aids I will not dispute, but that he should have found it convenient to do so is impossible. A scale for proportional measurement was invented by him for the use of sculptors, and is still the most convenient known, and the most simple.

The system of measurement which has been general in Italy for a vast number of years, though there is no record of when it was first used, is a system of triangulation. A model is produced of the same size as the proposed statue in marble. On this model three principal points are determined: two on the base as far apart as possible, and one as near the top of the statue as practicable. A sort of T-square of wood is then constructed, which has a steel point at the end of each of its three arms, and is of such proportions that the steel points each rest on one of the three principal points on the model. This T-square is then transferred to the block of marble, and the three principal points are assumed where the three steel points rest on the block. It is obvious that with this arrangement, any point on the model can be easily obtained on the marble by the use of ordinary compasses; for if we measure the distance of the required point from each of the three principal points on the model, and also measure the depth in, from a point assumed on the T-square, and transfer these measurements to the marble, we shall be able by carefully cutting away the marble, and repeated trials, to find with extreme accuracy a point which will coincide with all the four measurements, and which is the point required. In this way point after point can be found all over the figure, and a replica in marble of the original model is produced with mathematical accuracy. The introduction of this system was obviously of the highest importance to art, as it enabled the artist to depute to his assistants the roughing out and preparing of the work in marble, thus economizing his own time and labor. This system, however, perfect as it is in the hands of careful and skillful workmen, is not altogether without drawbacks. Mistakes may arise from a careless workman taking one pair of compasses for another, or from want of accuracy in measuring from point to point; also, there is a great loss of time, from the fact that each point requires at least three measures to be taken. To obviate this inconvenience, what is known as the "scale-stone instrument" was invented, I believe in England, where alone it obtained any considerable use. The instrument consisted of two blocks of stone, one and sometimes more sides of which where squared up true with the surface. An iron bar formed like a strap passed horizontally along the trued-up side. Between this strap and the side fitted an upright, held in place by a wedge. An arm moving on a universal joint was fastened to this upright, sliding up and down it on a sleeve. At the extreme end of this arm was another universal joint, with a short arm bearing a pointer or needle. All of these joints could be clamped immovably. The model being fixed on the scale-stone, and the block of marble on the other, the upright was now placed in the strap and tightened up by the wedge. The arms were now moved until the pointer rested exactly on the point to be transferred to the marble; all the joints were then clamped up except the needle, which had a little stop put on it and was then withdrawn, it being fitted in a slide. The wedge was then loosened, and the instrument transferred to the other scale-stone, wedged up, and the pointer slid forward; the marble being cut away to allow its motion, until it came against the stop, its point touching the marble at the same time indicated the exact point required. This instrument had many good qualities, but the use of scale-stones was highly inconvenient, and although it was popular in England, the foreign artists would not use it, as they found that the saving of time was more than counterbalanced by the inconvenience of being unable to move the work, and, moreover, they accused the instrument of being inaccurate.

Within the last seven or eight years a

great improvement has been made in pointing instruments, and before long the old instruments will have entirely disappeared. The new instrument, in its latest and most perfect form, consists of two metal tubes, one about 15 in. long, the other about 2 ft. 6 in. The longer one has a strong, steel hook at the one end, the other passes through a sleeve on the middle of the other tube, and can be clamped up tight. The short tube has near each end a sleeve which bears a steel point. This part of the instrument is neither more nor less than the T-square I have already mentioned as used in pointing by triangulation. The steel hook can be removed and replaced by a straight point when required. As a rule, it is hooked on to a point assumed on the head of the statue. On the long bar of this T slides a sleeve, to which is fixed another sleeve at right angles across it. In this second sleeve slides another rod or tube, which in its turn carries another couple of sleeves like those already mentioned, so that the right-angle one is smaller than the other, and carries a smaller rod. At the end of this smaller rod is a ball and socket joint, bearing the sliding needle or pointer described in the scale-stone instrument. This instrument is wonderfully light and handy, and very accurate, and can be used with the work in any position. There is one great drawback, however, to these instruments, they will not work proportionally. You can only use them to produce a work on the same scale as the model. But it is often of great convenience for an artist to be able to enlarge from a smaller design; and much ingenuity has been bestowed on the invention of methods of enlarging and reducing. Every draughtsman is acquainted with the usual old and tedious methods of enlarging and reducing, and the Pantograph is so well known that I need not waste time in describing it. Photography has also helped us somewhat, and is quite convenient for making reductions, but not so for enlargements on any considerable scale. For this latter I have recently seen an arrangement which seemed so satisfactory that I asked the permission of the inventor, Mr. Henry Holiday, the well-known artist, to mention it. It consists of a dark room, about 7 ft. square and 10 or 12 ft. high. In the front of this room is an opening closed by a canvas and paper bellows tapering in form, which can be drawn out several feet long, the smaller and movable end of which is closed with a camera lens. This lens, and its bellows, is supported on a frame which travels backwards or forwards on guides on the floor according to the distance required. Opposite to the lens a screen is placed, and very strongly illuminated. The sketch or drawing to be enlarged is placed against this screen, but inverted. The bellows is drawn in or out, and the proper focus obtained according to the proportion required by the artist, who then finds his sketch inside the dark room projected right side up on a paper screen of the size required, and he has only to trace it off. Mr. Holiday showed me several most interesting experiments with this instrument; amongst other things we enlarged some small photographs of sculpture to full life size, and the same with some photos and drawings from nature, and the result was highly satisfactory. The enlargement of drawings, however, important as it is, is not so serious an affair as enlarging sculpture. This is a subject which has attracted the attention of some of our ablest men. Scores of patents have been taken out for this purpose, and Watt and Chantrey rre said to have joined forces to effect it, but do not seem to have been altogether successful. The most usual and best approved plan has been to work with the three compasses, as in ordinary pointing by triangulation, and transferring the measures taken with the compasses on the small model to the larger measures required by means of the scale of Michael Angelo. This scale is formed as follows: Given a statue of any size to be enlarged to whatever you like, draw on the wall, or any other convenient place, a vertical line, mark off on that line the exact length of the enlarged statue. Then take in your compasses the measure of the small statue, and placing one point of the compass on the point which marks the base of your statue on the large scale, draw a circle with that radius, then draw from the point which marks the top of your large figure a line tangential to that circle, and you have the scale of Michael Angelo. If, now, you wish to transfer any intermediate measures, you take such measure in the compasses, place one

point on your vertical line, and run it along until you find a point where the other arm of the compass will just touch the opposite line without crossing it. From the point of your compass on the vertical line to the apex of the angle formed by the two lines of the scale, is the measure required. This system of enlarging is, in my opinion, the usual plan pursued by Michael Angelo, and may probably have been invented by him, which would account for the scale bearing his name. But the danger of error is very considerable, for a careless workman taking inaccurately any measure on the small model, transfers this initial error to the large scale plus any further inaccuracy that may creep in through elasticity of compasses or other causes, and a very slight initial error becomes a very serious one at the last on the large scale. To get over this difficulty many attempts have been made to produce a pointing instrument that should allow no chance of error to the workman, and it was even proposed that he should not even be allowed to cut away the marble, but that the machine should do all. The difficulties in the way of producing a machine capable of turning out a large marble statue from a small highly finished model were so great, that for artistic purposes, the attempt has been abandoned. The difficulties were elasticity of material, and wear and tear of tools, and unequal expansion and contraction of parts. These causes were ever at work producing ever-varying results. Still, although these machines would not enlarge satisfactorily, some of them would reduce very well indeed, and when made on a small scale, turned out very beautiful work in ivory or similar material. The Colas machine is the best example of this type; I will therefore describe it. It consists of a cast iron bed on which are two revolving tables. These tables can be placed at varying distances from each other as may be required. They are revolved at equal angular velocity by means of an endless chain. At one end of the bed there is fixed a universal joint from which proceeds a pantograph suspended by cords and weights from a frame above. This pantograph being free to move in any plane, and being counterpoised as just mentioned, is used as follows:—The figure to be copied is placed on the table farthest from the universal joint and securely chucked.

The pantograph is set to the proportion required, and the other table is brought into position opposite the reducing point of the pantograph, the chain is tightened up by means of an idle wheel, and the instrument is in order. A block of plaster is now chucked on the reducing table, and the operator takes in his hand the reducing point, which is a cutting point of hard steel, and with it cuts or rather scratches away the surface of the plaster block, until the other, or enlarging point, strikes the surface of the model. He continues this process until there is no more plaster within reach of his cutting point, and then he makes the tables revolve so as to bring fresh material within reach, and so on, until no more remains to be cut away. This seems simple enough, but as he is obliged to work this pantograph in very different planes, in order to get at the different parts of the work, the strains on the instrument are constantly varying, and materially affect the accuracy of the work. Of course the larger the instrument the greater would be this variation. To get over this difficulty it has been found necessary to restrict very materially the size of the instrument, and also to cut the models in pieces and make the reduction of each piece separately, in order to avoid as much as possible the necessity of working in widely differing planes. Yet in spite of all this, the result is not altogether satisfactory, even for reductions. Some errors are sure to creep in in joining up the various parts of the model, and these are almost as objectionable as errors due to the machine itself. I believe this machine to be the best extant, and it has maintained its reputation against all of similar construction for nearly thirty years, but I speak of it from experience. About fourteen years ago I desired to have a statue I had just completed reduced to half-size for bronze-casting. I accordingly sent a plaster cast of this statue to Paris, to the patentees, keeping a cast out of the same mould for myself. In due course the reduction was sent to me, but it did not look quite right. I did not know what was wrong, but I was not satisfied. I called in a brother sculptor, and he also noticed the difference. We held a consultation, and decided to test this reduc-

tion by the scale of Michael Angelo. We accordingly projected the scale on a slate table, and found that the scale of the reduction was not only not 1 to 2 as ordered, but that the small model did not agree exactly to any particular scale, in short it was as full of small errors as any fairly good free hand copy would have been. Of course under these circumstances I declined to pay more than the ordinary value of a hand copy, and the result was that I paid that amount, and they took it, and did not fight, knowing the result would be to depreciate the value of their machine if they brought the case before the courts. Two or three years ago, some Frenchmen had an instrument in Regent Street, which was merely a large Colas machine, neither more nor less, which they were endeavoring to use for enlarging sculpture, and were desirous of getting up a company for the purpose. The project was absurd, and the machine quite incapable of doing very accurate work. There is no existing machine that does. But although it is very difficult to make a machine that will carve on a large scale, it has always seemed to me that it would be very possible to produce an instrument that would take all the responsibility of measurement off the hands of the workman—an instrument which could be set to any scale, and which should tell the workman exactly where he had to cut away the marble, and exactly how much. I often talked over this project when I resided in Rome with my friend Mr. Cardwell, the sculptor, a very able mechanic, and he made some attempts at the construction of an instrument of this description, but was not very successful, except in so far as to show the difficulties as well as the possibilities of the undertaking. This was about eighteen years ago. Five or six years ago I again turned my attention to this subject, and at last succeeded in producing an instrument which I named the Inconograph, but which my workmen christened Polly, a name which has stuck to it.

It is obvious that in a short paper like this it is impossible even to enumerate the half of the ingenious mechanical contrivances which have been invented for the benefit of the arts, or even the less numerous names of those engineers who have also been artists. The subject would require a good sized volume, and would, I think, prove interesting reading. I have merely attempted to skim over the surface of the subject; but if I have not proved that engineers ought to be artists, at least I trust I have shown that artists have much to gain by studying the science of mechanics, and by frequenting the society, and cultivating the friendship of civil and mechanical engineers.

THE ROCKNER-ROTH PROCESS FOR THE PURIFICATION OF SEWAGE AND WASTE WATER FROM FACTORIES.

From "Gesundheits-Ingenieur" for Abstracts of the Institution of Civil Engineers.

This process, which has been in operation in Dortmund, furnishes a ready means for the purification of manufacturing waste liquids. It is both mechanical and chemical in its action. The chemicals employed vary in accordance with the composition of the water to be dealt with, but it is claimed that the utilization of these compounds is so complete that a relatively small quantity suffices, entailing only a moderate cost. After the addition of the chemicals a separation from the liquid takes place of the suspended and dissolved impurities and the matters resulting from the chemical reaction. The subsequent mechanical treatment consists in the introduction of the mixture into a simple apparatus, in the form of an upright cylinder about 7 meters (22.96 feet) high, whose diameter is regulated by the volume of liquid to be treated in a given time. This vessel has certain pipes connecting it with a small air-pump, the dimensions of which for the treatment of 200 cubic meters (44,000 gallons) per diem were as follows: cylinder, 75 millimeters (2.95 inches) in diameter; stroke, 210 millimeters (8.26 inches). It was found practicable in 8 minutes with this pump to exhaust the

air entering the receiver in the course of 5 hours; so that a similar pump, used continuously, would suffice for the daily purification of upwards of 7,000 cubic meters of sewage. Owing to the vacuum produced in the receiver, the external atmospheric pressure slowly forces up the sewage water, together with the precipitate, and this mixture undergoes complete separation of the liquids from the solids. Then by a siphon-like contrivance which is entirely self-acting and continuous in its operation, the purified liquid is caused eventually to flow away at the top of the vessel. Arrangements are made for the escape of oil and the specifically lighter matters at the upper part of the siphon.

By the action of the apparatus, the necessary slow upward movement of the liquid is effected, and by this means also the specifically heavier, suspended matters, and the precipitate resulting from the chemical treatment are deposited at the bottom. Layers of sludge are thus formed in the lower part of the receiver and in the basin beneath it, from which latter the deposited matters may, either continuously, or from time to time, be withdrawn, mingled with a small proportion of the liquid. The presence of this layer of sludge is of much importance, as it acts as a species of filter for the subsequent volumes of sewage, and avoids the waste of chemicals, which in former cases, and under ordinary methods of precipitation at once fall to the bottom of the tank and no longer act on the liquid under treatment. The following are among the advantages of the process set forth by Dr. Kaysser, of Dortmund: Absolute separation of the suspended, and to a great extent also of the dissolved mineral impurities, and the production of a clear, colorless effluent, free from smell. The removal from the water also of the gaseous admixtures, thereby rendering it incapable of supporting the life of the lower organisms; the water remaining slightly alkaline after the treatment, no free sulphuretted hydrogen can be present. The sludge contains all the matters of use to the agriculturist, in the form of a dense and readily utilizable mud; and moreover the purification is effected in an enclosed space, and can therefore give rise to no pestilential effluvium.

G. R. R.

THE DISTRIBUTION OF ELECTRICAL ENERGY BY SECONDARY GENERATORS.

By J. DIXON GIBBS.

From "Iron."

THE remarkable results obtained during the last few years from the production of electrical energy and its application to lighting purposes as well as to the transmission of mechanical power, have naturally brought into prominence the great problem of the distribution of electricity. In a complete system of electrical distribution, it is necessary that electrical energy in all its forms should be at the disposal of individual householders, whatever the service they may require it to perform; that is to say, if light is desired, currents should be available at will for feeding every type of lamp, whether arc or incandescent. If mechanical power is required, motors should supply it; whilst currents suitable for electro-chemical purposes should be obtainable with equal facility. The distribution should be over a large area, central stations being preferably situated in the outskirts of towns at a distance from the area to be supplied. Where water power exists it should be utilized, or, if steam power is used, a site should be chosen in proximity with water so as to secure the economy in fuel effected by the employment of condensing apparatus.

It is scarcely necessary to remark that nothing hitherto done in the way of street lighting or of lighting large establishments, such as theaters, hotels, and public buildings, by means of machinery on or near the premises, can be claimed to constitute a distribution of electrical energy.

The same may be said of the transmission of a given force to a single point. This is not a distribution of mechanical power. Gas and water companies do not set up separate works for the supply of special consumers, but from central stations distribute to all consumers in conformity with their several requirements. In order to arrive at the results just described as necessary to a complete system of electrical distribution, the following conditions are essential :—

1. Every receiving apparatus must be supplied with its proportion of electrical energy, so that it may act independently of the others and without affecting them.

2. The regulation must be automatic, instantaneous in its action, and require no attention.

3. The regulation must be of such a nature that the generating dynamo machine shall produce each moment the exact amount of electricity necessary to supply all the apparatus in action.

The chief difficulty in realizing these conditions has been that the intensity and E. M. F. of an electric current being always exactly determined, the uses to which the current can be put are necessarily limited to feeding apparatus of a given resistance and of an electrical capacity, in harmony with the quantity of available electricity, from which it results, that by means of a given current it is only possible to employ apparatus of consumption of identical construction, that is to say, connected together under certain conditions of resistance that must be maintained constant.

The author need not review the various systems, more or less ingenious, which have been invented during the last few years with the result, not of solving, but of going round, the difficulty, for in the interesting lectures recently delivered by Professor Forbes before the Society of Arts, the mechanism of all these combinations has been ably explained. It seems, however, to have resulted from the facts adduced in these lectures :—

1. That the future of electrical distribution lies in the direction of the employment of currents of high potential and small quantity, requiring conductors of small diameter.

2. That the employment of an apparatus, by means of which the factors of the initial energy can be transformed to suit the requirements of each consumer, is essential to the solution of the problem which we are discussing this evening, and the secondary generators under review are such transformers. They are known as the Gaulard-Gibbs secondary generators. The phenomena of induction which have immortalized the name of Faraday are utilized in these instruments. Numerous predecessors have certainly conceived the idea of utilizing secondary currents localized and of different kinds, but coming later in this path of research, the inventors of the secondary generators have labored under more propitious circumstances, because results already arrived at have enabled them to produce these phenomena under such conditions that their employment has been rendered absolutely practical and economical. This consideration certainly inspired them with the courage to pursue with perseverance those researches to which their predecessors had given but passing attention.

However this may be, the present inventors have regarded the employment of these phenomena from a purely industrial point of view. Their first thought after having experimentally verified the actual transformation of primary electrical energy into electrical currents of different kinds, and capable of being applied to every practical purpose, was to make a careful analysis of the phenomena observed. They were thus able to determine the special conditions under which the primary and secondary circuits would yield the highest effective and most economical return for the energy expended ; they arrived at the conclusion that the two circuits, inducing and induced, must have the same mass of metal and a position absolutely symmetrical with the common magnetic field. Since it is upon the determination of these conditions that the invention of the secondary generator is based, it may be interesting to know that these conditions, which are a *sina qua non* of an economical return, have never been previously determined.

But it was not sufficient to determine philosophically what the industrial conditions should be, it was also necessary to realize them practically. The inventors accordingly constructed their apparatus with a sufficient number of spirals to produce the required practical E. M. F

by means of a cable formed of an inducing circuit of low resistance surrounded parallelly to its axis by forty-eight wires composing the induced circuit, the sum of the sections of which was equal to the section of the inducing circuit. By means of this arrangement the theoretical conditions already alluded to were approximately fulfilled, since the mean distances of the induced circuits from the magnetic field were equal to the distance of the inducing circuit from the same magnetic field. Further, it was easy to group the extremities of the secondary wires so as to give to the factors E. I. of energy the different values required according to the work to be done. These apparatus served, during five consecutive months, without interruption, to light with arc and incandescent lamps, five stations of the Metropolitan Railway, one apparatus being placed at each station. The primary circuit in which they were placed was composed of a single wire 15 miles in length and $\frac{1}{8}$ of an inch in diameter. This primary circuit was metallically closed throughout its entire length with the terminals of the dynamo machine at Edgware Road. The results as regards effective work formed the subject of a report by Dr. Hopkinson, the conclusions of which were perfectly satisfactory, and are too well known to require repetition.

The anticipations of an economical return having been thus fulfilled, the next step was to seek the most simple and practical methods of applying economically the principle upon which the construction of the apparatus reposed. These researches led to the formation of the inducing and induced circuits by means of copper discs superposed and furnished with ear pieces for the purpose of connecting them together. This arrangement, which allows of the juxtaposition of the two circuits, has also the advantage of permitting the employment of any insulating material that may be found to give the best results. The simplicity of this method of construction is obvious; the weight and size of the apparatus are remarkably small in relation to the work it is capable of performing.

The apparatus is identical in form with the generators exhibited at Turin.

It is worthy of remark that in these apparatus the actual resistances of the inducing and induced circuits are kept as low as possible, so as to render the work expended in the interior circuits very small in proportion to the work available in the exterior circuits. As an example, take the instrument we have before us: it is intended to supply in the exterior circuit an effective work of 750 Watts under the influence of a primary current of 12 amperes—the total resistance of its two circuits induced and inducing is $\frac{3}{10}$ of an ohm, so that $12^2 \times \frac{3}{10}$ Watts represents the work absorbed by the apparatus, and, consequently, useless; thus the theoretical loss of energy resulting from the interposition of these apparatus is $\frac{43.2}{750}$, or $5\frac{1}{2}$ per cent. Nevertheless, when the inventors announced an effective return of 90 per cent., many doubts were expressed in consequence of the unfavorable results hitherto obtained from researches in the same direction—these doubts were really testimonies to the novelty of the results—it remained only to demonstrate conclusively the truth of these results. The authority of an eminent electrician had been insufficient to carry conviction to every mind. An exceptional circumstance, however, enabled the inventors to determine definitely, without room for further question, the accuracy of their assertion.

In the month of January, 1884, the Italian government offered a grand prize of 10,000 fr., to be competed for internationally for the most important advance made in the transport of electrical energy to a distance, and invited other governments to name representatives who should constitute a jury for deciding the question. The Italian government was probably influenced in taking this step by the conviction that the industrial development of Italy would be largely aided by the prompt utilization of the vast natural forces in which the country abounds. The jury was composed of: M. Tresca, membre de l'Institut de France, honorary president; Professor Ferraris, acting president; M. Wattmann, rector of the University of Geneva; Professor Voit, of Munich; Professor Webber, of Zurich; Professor Roiti, of Florence, member of the International Commission for the determination of the ohm: Professor Kittler, of Darmstadt; Professor Cossa, of the School of Engineers at Turin; Professor Farini, of Milan, &c. Profes-

sors Voit and Kittler were the gentlemen deputed to take electrical measurements at the Vienna and Munich Electrical Exhibitions.

Practical experiments of the distribution of electrical energy by means of the secondary generators were made under conditions which M. Tresca, in the name of the international jury of the Turin Exhibition, communicated to the Académie des Sciences de Paris, in terms of which the author will read a translation. The original was published in the *Lumiere Electrique* of October 18, 1884. It runs as follows: "An International Electrical Exhibition is now being held at Turin, in connection with which an important prize is offered by the Italian government and the town. I am charged by my colleagues of the jury of this exhibition to bring to the notice of the Académie the following facts: Messrs. Gaulard and Gibbs have established at the exhibition, the station of Lanzo, and the intermediate stations, a circuit whose length, including return, is 80 kilometers by means of a bronze chrome wire 3.7 millimeters in diameter without covering. This wire carries an alternating current produced by a Siemens electro-dynamic machine of the 60 horse-power type in such a way that the current can be simultaneously utilized for different modes of lighting, whether at the exhibition, or at the Turin station, or at the Lanzo station, or at the intermediate stations, by its transformation at each point of the two factors constituting its energy by means of the secondary generators of the new type, shown by Messrs. Gaulard & Gibbs. On September 25, we verified the simultaneous regular working.

"1. At the exhibition of the following apparatus, which had to be necessarily supplied with very different potentials—nine Bernstein lamps, one Sun lamp, one Siemens lamp, nine Swan Lamps, and five other Bernstein lamps situated at a small distance.

"2. At the Turin Lanzo station, 10 kilometers away, thirty-four Edison lamps of sixteen candles, forty-eight of eight candles, and a Siemens arc lamp.

"On September 29, the experiments were still more conclusive, the system being extended to the Lanzo station, 40 kilometers distant, by the perfectly regular action of twenty-four Swan lamps of 100 volts. The numerous transformations required by the variety of these different methods of lighting are effected with accuracy, and, although we are not able to give the exact figures, it is perfectly demonstrated that the secondary generators may be considered, at all events within certain limits, as transformers giving a relatively large return of the energy of alternating currents. The actions of lighting and extinction are effected without any disturbance (of the other lights) and by means of simple commutators. The principal object of this communication is limited, however, to testifying to the complete success of a distribution of different modes of lighting over an (effective) distance of 40 kilometers. The importance of the realized fact alone demands that it should be fixed by a precise date, but it should be borne in mind that we are not dealing here with the transport of mechanical power."

More than 300 Italian engineers and architects who had witnessed the experiments, assembled for the 1884 congress, passed a resolution of which the author will read a translation. "The fifth congress of Italian Engineers and Architects cannot ignore the great importance of the experiments now being made at Turin by means of the Gaulard and Gibbs secondary generator, and, having examined the working of such a system of distribution, record the hope that the government, the corporations of towns, and manufacturers will patronize this system, and that the expectations which five months of trial on the Metropolitan Railway, the experiments at Turin, and the sound scientific conceptions upon which the system is based have raised in the field of science and industry, may thus be realized."

The measurements taken by means of the electrometer of Mascart of the effective return of the secondary generators are shown by the curves on the diagram, fig. 2. In taking for abscissæ the resistances introduced in the secondary circuit, and for ordinates the primary and secondary work, it will be seen that the progression, at first increasing, arrives at its maximum between the resistances of 6 and 10 ohms, which are the resistances under which the apparatus works normally, but these measurements having been considered by some members of the

jury not absolutely free from theoretical objections, a commission was appointed by the jury, composed of Professors Webber, Voit, Roiti, and Ferraris, to prepare a calorimeter, by means of which Professor Ferraris carried on his experiments during seven consecutive days, and arrived at the conclusions which formed the subject of a special report, which is very voluminous. The conclusions of this report are condensed in the table of which the following is a copy, and which gives an average practical return (column (N)) of 94 per cent. when the apparatus worked under the conditions for which they were constructed.

In the annexed table are shown the theoretical and practical co-efficients of the return from a secondary generator coupled in tension, calculated in the following manner, for a series of resistances of the secondary circuit. In column R the values of the total resistances of the secondary circuit vary from 0.28 to 40.0 ohms. In column M are shown the theoretical values of the coefficient of the total return. In column N are shown the values of the coefficient of the exterior theoretical return, and in column (N) the values of the coefficient of the exterior practical or effective return.

R.	M.	N.	(N.)
0.28	0.500	0 000	0.00
2	0.876	0.753	0.74
4	0.933	0.867	0.86
6	0.956	0.911	0.90
8	0.962	0.928	0.92
10	0 967	0.940	0.93
12	0.971	0.948	0.94
14	0.973	0.954	0.94
16	0.974	0.957	0.95
18	0.975	0.959	0.95
20	0.975	0.961	0.95
22	0.976	0.963	0.95
24	0.976	0.964	0 95
26	0.975	0.964	0.95
28	0.975	0.965	0.95
30	0.975	0.966	0.96
32	0.974	0.966	0.96
84	0.973	0.965	0.95
36	0.973	0.965	0.95
38	0.972	0.965	0.95
40	0.971	0.965	0.95

Now that the secondary generator has been absolutely demonstrated to be a perfect transformer of the energy of alternating currents, it only remains to the author to examine whether the conditions under which these instruments act are in perfect accord with the conditions laid down at the commencement of this paper for the solution of the problem. In order to thoroughly understand that this is so, let us suppose that we have to distribute 10,000 glow lamps, 200 arc lamps, and 200 mechanical horse-power in varying proportions, over a circuit 15 miles in length. The author adopts these figures because they represent somewhere about the average requirements of the future. With the aid of the secondary generators this distribution would be effected in the following manner:—

The initial electrical work would be produced by four alternating-current dynamo machines, of the Siemens model, for example, supplying 100 amperes and 3,000 volts each. This work would be distributed over four distinct circuits, metallically closed with the terminals of each dynamo, and formed of a cable having a diameter of one centimeter only, connected with the secondary generators, one of which would be placed in the house of every consumer. The form and size of these secondary generators would necessarily be proportioned to the quantity of work required of each one respectively. It may be remarked here that the secondary generators, fed by an electrical quantity which is constant, develop on the current which feeds them a counter electro-motive force which is proportionate to the work they develop in their external or secondary circuits. From this it follows that the quantity or ampere value of the primary current must remain fixed, whatever may be the number of secondary generators to be fed, and that the E. M. F. only of the primary current will vary according to the sum of the resistances set up by the number, more or less important, of the generators in action on the circuit. This result is automatically obtained by means of a regulator of intensity, which, placed in the primary circuit, acts upon the derivation of the exciting machine, by introducing variable resistances, so as to proportion the intensity of the magnetic field of the generating dynamo machine to the E. M. F., which it must develop in order to overcome the resistance opposed by the secondary generators in action.

It is necessary to remember that the work developed by the secondary generators depends absolutely upon the number of spirals of which each is composed, and the form of energy developed depends on the manner of grouping these spirals. From this it follows that each consumer may, as it pleases him, put his apparatus in action, and cause it to produce the special form of energy he wishes to employ without troubling himself about his neighbors. The most absolute independence of each apparatus, and an automatic proportioning of the work produced to the work expended, permit the realization by this system of the essential conditions already indicated for enabling a distribution of every alternating form of electrical energy in currents resulting from the phenomena of induction, which produce always, and necessarily, the alternating form of current.

The old ideas, attributing special danger to the employment of alternating currents, have been ably corrected by Professor Forbes, Dr. Hopkinson, and others; but it is worthy of remark that in an installation under the system the author is discussing—whatever may be the E. M. F. of the primary current, which, it must be remembered, circulates always in a closed circuit—the difference of potential between the terminals of the secondary generators will never be greater than that necessary for the lamps fed by them—that is to say 100 volts or 50 volts, as the case may be. Nothing, therefore, short of culpable carelessness could possibly give rise to a condition of things presenting any danger whatever to the public.

If consumers required electrical energy only for producing light, a solution brought to this point would be as complete as possible; but the applications of continuous currents are too numerous not to render their distribution also desirable, and that with the same facility which, it has been shown, attends the distribution of alternating currents.

It has been already pointed out that the *sine qua non* of the practical and economical transport and distribution of electrical energy to a great distance is to give to the energy to be transported the form of small quantity and high tension, or E. M. F. But although the known types of alternating-current dynamos adapt themselves with the greatest facility to the production of currents of the highest E. M. F., this is, unfortunately, not the case in regard to the collection of continuous currents of a higher E. M. F. than 2,000 volts. On this account the inventors of the secondary generators sought and found a means of redressing the alternating currents produced by their secondary generators. These currents, it will be remembered, have already, by transformation, a low E. M. F., that is to say, they are in the form most readily utilizable. On November 16 last, Professor Ferraris, president of the International Jury of the Turin Exhibition, witnessed the perfect redressing of a current produced by a secondary generator—this current had 16,000 changes of direction per minute.

The instrument for redressing an alternating current is composed of several electro magnets coupled in series and fixed on a cast iron frame, a similar number of electro magnets attached to a movable frame turning on its axis, a redressing commutator fixed on the same axis, having as many changes of polarity as bobbins, and lastly of collectors receiving the currents. The alternating current enters by the fixed bobbins traversing them in series; the point where the current leaves is attached to the brush which communicates with the commutator; the opposite pole communicates directly with the other brush. These brushes are so arranged that they can never come into contact with the same metallic pieces. If the apparatus is at rest, the movable electro magnets are also traversed by the alternating currents; but as soon as the apparatus begins to work, the commutator inverts the poles of the movable electro magnets. When the speed has reached the synchronism of the alternations, the current becomes continuous in the movable bobbins, and maintains the synchronism. It is necessary only to take a derivation on the collectors to have a continuous current.

This instrument has, then, the property of taking, under the influence of a very small alternating current, a speed which is synchronic with the changes of direction of the current which feeds it. Thus, then, until it has been found possible to do important work with continuous cur-

rents of high E. M. F., the secondary generators will enable the distribution in all its forms, whether alternating or direct, whether of high or low potential of electrical energy, over distances sufficiently great to enable the practical utilization of natural forces. The value of the progress thus realized has been officially recognized in Italy by a grand prize of 10,000 francs.

Besides installations in Italy and elsewhere, there is one now in course of preparation, of which the central station is situated in New Bond Street, which will doubtless be studied with interest. This installation will consist of the distribution of more than 5,000 lamps of various systems—the steam engines now being placed in position are of over 600 horse-power indicated, and have been manufactured by Messrs. Marshall & Company, of Gainsborough. The dynamos to be used are by Messrs. Siemens Brothers, and are the largest yet made by that firm; they have already been tested, and give most satisfactory results. An excavation of 6,000 square feet has been made under the Grosvenor Gallery, and in this space the machinery is being placed.

It may be interesting to mention that, pending the laying down of the large engines, a temporary engine of 30 horse-power nominal is driving two Siemens W′ dynamos coupled in parallel, which give a current of 24 amperes and 800 volts. This current traverses sixteen secondary generators of 2 horse-power each, which supply currents for 300 glow lamps distributed in the library and club at the Grosvenor Gallery, and in two adjoining establishments in Bond Street. When the satisfactory working of the permanent installation shall have been demonstrated, it is not unreasonable to expect that a wide extension of the application of electricity for the purpose of house-to-house lighting upon the principle described by the author will take place.

HYDRAULIC TABLES BASED ON THE FORMULÆ OF D'ARCY AND KUTTER.

By P. J. FLYNN, Mem. Tech. Society.

From Transactions of the Technical Society of the Pacific Coast.

THE object of this paper is to show how the work of computation required for the solution of problems in hydraulic engineering is very much diminished by the use of the following tables. It is believed that these tables will be of material help to hydraulic engineers who make it a practice to use the formulæ of D'Arcy and Kutter in the solution of problems relating to pipes for the flow of water.

In the following formulæ let—

V = velocity in feet per second.

Q = discharge in cubic feet per second.

C = coefficient of mean velocity.

S = fall of water surface (h), in any distance (l), divided by that distance $= \frac{h}{l}$ = sine of slope.

a = area of cross section of pipe or conduit in square feet.

p = wetted perimeter of pipe or conduit in lineal feet.

r = hydraulic mean depth in feet = area of cross-section of pipe or conduit in square feet (a) divided by its wetted perimeter in lineal ft. $p = \frac{a}{p}$

d = diameter of pipe or conduit.

n = the natural coefficient, the value of which depends on the nature and condition of the bed of the channel through which the water flows, or in other words, its degree of roughness.

The plan on which the tables are constructed will be briefly stated here and their use will be more fully explained at the end of the paper.

Chezy's general form of formula for velocity is—

$$V = c\sqrt{rs} = c\sqrt{r} \times \sqrt{s}$$

therefore

$$Q = ac\sqrt{rs} = ac\sqrt{r} \times \sqrt{s}$$

The factors on the right hand side of the equations are tabulated, $c\sqrt{r}$ and $ac\sqrt{r}$ for diameters usually adopted in practice, and $\sqrt{s}$ for several slopes.

Now to find the velocity, the diameter and slope being given: Look out and note down the number representing $c\sqrt{r}$ in its column and opposite the given diameter; also look out rnd note down the number respresenting $\sqrt{s}$ opposite the given slope. The product of these two numbers will give the required velocity. Again, given the slopeand velocity in feet per second to find the diameter. From the equation

$$V = c\sqrt{r} \times \sqrt{s}$$

we have

$$c\sqrt{r} = \frac{V}{\sqrt{s}}$$

Look out the value of $\sqrt{s}$ corresponding to the given slope and divide the velocity by it. The quotient will be the value of $c\sqrt{r}$. In the column of $c\sqrt{r}$ look out the nearest number to the value of $c\sqrt{r}$ so found, and opposite to it in the same line will be the diameter required. At the same time the area and hydraulic mean depth can be found on the same line and the discharge can be found by looking out the value of $ac\sqrt{r}$ and dividing it by $\sqrt{s}$. In fact by inspection of the tables and the multiplication or division of two numbers, problems can be rapidly and accurately solved, which, by the use of any one of the formulæ, would be a tedious and troublesome operation. When the value of $c\sqrt{r}$ or $ac\sqrt{r}$ is found, the diameter can at once be found by inspection.

When the slope and velocity are given and the diameter is required it is not found directly. The value of $c\sqrt{r}$ is first computed by formula (10) and in the same line with this value in the tables will be found the required diameter. In a similar way the slope and discharge being given and the diameter required. The value of $ac\sqrt{r}$ is first computed by formula (15) and in the same line with this value in the tables will be found the required diameter.

The columns of $c\sqrt{r}$ and $ac\sqrt{r}$ can be used to compare velocities and discharges of pipes with equal slopes, and this can be done even when the channels have different degrees of roughness if the tables have been prepared from the same formula.

For instance, a pipe say of 3 feet diameter has a discharge of 20 cubic feet per second by D'Arcy's formula, and it is required to find the diameter of a pipe which shall discharge 30 cubic feet per second, that is an increase of 50 per cent., the slope being the same in both pipes. Find in Table 1 the value of $ac\sqrt{r}$ opposite 3 feet diameter and it is = 674.09, and this increased by 50 per cent. = 1011.1 = the value of $ac\sqrt{r}$ corresponding to the required diameter. By inspection of Table 1 the nearest value of $ac\sqrt{r}$ to this is found to be 1021.1 opposite a diameter of 3 feet 6 inches, which is the required diameter. In a similar manner velocities can be compared by the use of the column giving the values of $c\sqrt{r}$.

For feet measures D'Arcy's formula is

$$V = \left\{ \frac{rs}{.00007726 + \frac{.00000162}{r}} \right\}^{\frac{1}{2}} \qquad (1)$$

and from this we have

$$S = \left(.00007726 + \frac{.00000162}{r} \right) \frac{V^2}{r} \qquad (2)$$

In order to simplify, *substitute for r in feet the diameter d in inches*, and we have

$$S = \left(.00007726 + \frac{.00000162 \times 48}{d} \right) \frac{48\,V^2}{d}$$

$$\therefore\ S = \left(.00370848\,d + .00373248 \right) \frac{V^2}{d^2}$$

As the change will not materially affect the result, Mr. J. B. Francis, C. E., simplifies this into the form

$$S = .00371 \left(d + 1 \right) \frac{V^2}{d^2} \qquad (3)$$

$$\therefore\ V = \left\{ \frac{S\,d^2}{.00371\,(+1)} \right\}^{\frac{1}{2}} \qquad (4)$$

In order, however, to further simplify the equation into the Chezy form of formula, which is the form required for the preparation and use of the table adopted by the writer, and given at the end of this paper, let equation (3) be transformed

TABLE 1.—Circular Pipes, Conduits, etc., flowing under pressure. D'Arcy's formula for clean pipes.

Table giving the values of a and r, and also the values of the factors $c\sqrt{r}$ and $ac\sqrt{r}$ for use in the formulæ.

$$V=c\sqrt{r}\times\sqrt{s} \qquad Q=ac\sqrt{r}\times\sqrt{s}$$

These factors are to be used only for clean pipes under pressure.

d=diameter in ft.	ins.	a= area in square feet.	r= hydraulic mean depth in feet.	For velocity $c\sqrt{r}$.	For discharge $ac\sqrt{r}$.
0	$\frac{1}{4}$	.00077	.0078	5.251	.00403
0	$\frac{3}{8}$	.00136	.0104	6.702	.00914
0	$\frac{1}{2}$	.00307	.0156	9.309	.02855
0	1	.00545	.0208	11.61	.06334
0	$1\frac{1}{4}$	.00852	.0260	13.68	.11659
0	$1\frac{1}{2}$	.01227	.0312	15.58	.19115
0	$1\frac{3}{4}$	.01670	.0364	17.32	.28936
0	2	.02186	.0417	18.96	.41357
0	$2\frac{1}{2}$	0.0341	0.052	21.94	.74786
0	3	0.0491	0.063	24.63	1.2089
0	4	0.0873	0.084	29.37	2.5630
0	5	0.136	0.104	33.54	4.5610
0	6	0.196	0.125	37.28	7.3068
0	7	0.267	0.146	40.65	10.852
0	8	0.349	0.167	43.75	15.270
0	9	0.442	0.187	46.73	20.652
0	10	0.545	0.208	49.45	26.952
0	11	0.660	0.229	52.16	34.428
1	0	0.785	0.250	54.65	42.918
1	2	1.069	0.292	59.34	63.435
1	4	1.396	0.333	63.67	88.886
1	6	1.767	0.375	67.75	119.72
1	8	2.182	0.417	71.71	156.46
1	10	2.640	0.458	75.32	198.83
2	0	3.142	0.500	78.80	247.57
2	3	3.976	0.562	83.77	333.08
2	6	4.909	0.625	88.39	433.92
2	9	5.939	0.687	92.90	551.72
3	0	7.068	0.750	97.17	686.76
3	3	8.295	0.812	101.2	839.38
3	6	9.621	0.875	105.1	1011.2
3	9	11.044	0.937	108.9	1202.7
4	0	12.566	1.000	112.6	1414.7
4	3	14.186	1.062	116.1	1647.6
4	6	15.904	1.125	119.6	1901.9
5	0	19.635	1.250	126.1	2476.4
5	6	23.758	1.375	132.4	3146.3
6	0	28 274	1.500	138.4	3912.8
6	6	33.183	1.625	144.1	4782.1
7	0	38.485	1.750	149.6	5757.5
8	0	50.266	2.000	160.0	8043.0
9	0	63 617	2.250	169.8	10804.
10	0	78.540	2.500	179.1	14066.

into one with the *diameter d in feet* and it becomes

$$S=.00371\left(12\,d+1\right)\frac{V^2}{144\,d^2}$$

TABLE 2.—Circular Pipes, conduits, etc., flowing full. Kutter's formula with $n=.011$.

Table giving the values of a and r and also the values of the factors $c\sqrt{r}$ and $ac\sqrt{r}$ for use in the formulæ,

$$V=c\sqrt{r}\times\sqrt{s} \qquad Q=ac\sqrt{r}\times\sqrt{s}$$

These factors are to be used only where the value of n, that is the coefficient of roughness of lining of channel, =.011, as for surfaces carefully plastered with cement with one-third sand in good condition, also for iron, cement and terra-cotta pipes, well jointed and in best order, and also surfaces of other material equally rough.

d=diameter in ft.	ins.	a= area in square feet.	r= hydraulic mean depth in feet.	For velocity $c\sqrt{r}$.	For discharge $ac\sqrt{r}$.
0	5	0.136	0.104	26.76	3.6398
0	6	0.196	0.125	30.93	6.0627
0	7	0.267	0 146	34.94	9.3294
0	8	0.349	0.167	38.77	13.531
0	9	0.442	0.187	42.40	18.742
0	10	0.545	0.208	45.85	24.976
0	11	0.660	0.229	49.46	32.644
1	0	0.785	0.250	52.85	41.487
1	2	1.069	0.292	59.13	63.210
1	4	1.396	0.333	65.21	91.037
1	6	1.767	0.375	71.08	125.60
1	8	2.182	0.417	76.76	167.50
1	10	2.640	0 458	82.11	216.76
2	0	3.142	0.500	87.36	274.50
2	3	3.976	0.562	94.84	377.07
2	6	4 909	0.625	102.0	500.78
2	9	5.939	0.687	109.0	647.18
3	0	7.068	0.750	115.7	817.50
3	3	8.295	0.812	122.1	1013.1
3	6	9.621	0.875	128.3	1234.4
3	9	11.044	0 937	134.4	1484.2
4	0	12.566	1.000	140.4	1764.3
4	3	14.186	1.062	146.1	2072.7
4	6	15.904	1.125	151.7	2413.3
5	0	19.635	1.250	162.6	3191.8
5	6	23 758	1.375	173.1	4111.9
6	0	28.274	1.500	183 1	5176.3
6	6	33.183	1.625	192.7	6394.9
7	0	38.485	1.750	202.0	7774.3
8	0	50.266	2.000	219 7	11044.
9	0	63.617	2 250	236.6	15049.
10	0	78.540	2.500	252.5	19834.

$$\therefore\ V=\left\{\frac{144\,d^2\,S}{.00371\,(12\,d+1)}\right\}^{\frac{1}{2}}$$

but $d^2=16\,r^2=16\,r\times r=4\,d\times r$ substitute this value for d^2 in the last equation, and

TABLE 3.—Circular Pipes, conduits, etc.' flowing full. Kutter's formula with n=.013.

Table giving the values of a and r, and also the values of factors $c\sqrt{r}$ and $ac\sqrt{r}$ for use in the formulæ,

$$V=c\sqrt{r}\times\sqrt{s} \qquad Q=ac\sqrt{r}\times\sqrt{s}.$$

These factors are to be used only where the value of n, that is the coefficient of roughness of lining of channel =.013 as in ashlar and well laid brickwork, ordinary metal, earthenware and stoneware pipe, but not new, cement and terra cotta pipe not well jointed nor in perfect order, plaster and planed wood in imperfect or inferior condition, and also surfaces of other material equally rough.

d=diameter in ft.	ins.	a=area in square feet.	r=hydraulic mean depth in feet.	For velocity $c\sqrt{r}$.	For discharge $ac\sqrt{r}$.
0	5	0.136	0.104	21.20	2.8839
0	6	0.196	0.125	24.60	4.8216
0	7	0.267	0.146	27.87	7.4425
0	8	0.349	0 167	31.00	10.822
0	9	0.442	0.187	34.00	15.029
0	10	0.545	0.208	36.87	20.095
0	11	0.660	0.229	39.84	26.296
1	0	0.785	0.250	42.65	33.497
1	2	1.069	0 292	47.85	51.157
1	4	1.396	0.333	52.90	73.855
1	6	1.767	0.375	57.80	102.14
1	8	2.182	0.417	62.58	136.54
1	10	2.640	0.458	67.07	177.07
2	0	3.142	0.500	71.49	224.63
2	3	3.976	0.562	77 77	309.23
2	6	4.909	0.625	83 82	411.27
2	9	5.939	0.687	89.71	532.76
3	0	7.068	0.750	95.37	674.09
3	3	8 295	0.812	100.9	836.69
3	6	9.621	0.875	106.1	1021.1
3	9	11.044	0.937	111.3	1229.7
4	0	12.566	1.000	116.5	1463.9
4	3	14.186	1.062	121.4	1722.0
4	6	15.904	1.125	126.2	2007.0
5	0	19.635	1.250	136.4	2659.0
5	6	23.758	1.375	144.3	3429.2
6	0	28.274	1.500	152.9	4322.9
6	6	33.183	1.625	161.2	5339.7
7	0	38.485	1.750	169.2	6510.6
8	0	50.266	2 000	184.5	9272.6
9	0	63.617	2.250	199.1	12663.0
10	0	78.540	2.500	212.8	16709.0

$$V=\left\{\frac{144\times4\,d\times r\times S}{.00371\ (12\,d+1)}\right\}^{\frac{1}{2}}$$

therefore, *for feet measures* D'Arcy's formula for velocity is simplified into

$$V=\left(\frac{155256\ d}{12\,d+1}\right)^{\frac{1}{2}}\times\sqrt{rs} \qquad (5)$$

and putting the first factor on the right-hand side of the equation = c, we have

$$V=c\sqrt{rs}=c\sqrt{r}\times\sqrt{s}$$

Kutter's formula for feet measure is

$$V=\left[\frac{41.6+\frac{1.811}{n}+\frac{.00281}{s}}{1+\left(41.6+\frac{.00281}{s}\right)\frac{n}{\sqrt{r}}}\right]\times\sqrt{rs} \qquad (6)$$

and putting the first factor on the right-hand side of the equation = c we have

$$V=c\sqrt{rs}=c\sqrt{r}\times\sqrt{s}$$

In the solution of problems relating to pipes, of diameters different from those given in the tables, Kutter's formula (6) can be simplified in form by adopting it to a slope of 1 in 1,000. It then becomes when n=.013

$$V=\left\{\frac{183.72}{1+\left(44.41\times\frac{n}{\sqrt{r}}\right)}\right\}\times\sqrt{rs} \qquad (7)$$

and when n=.011

$$V=\left\{\frac{209.05}{1+\left(44.41\times\frac{n}{\sqrt{r}}\right)}\right\}\times\sqrt{rs} \qquad (8)$$

The velocity by these formulæ will be near enough to the true velocity for all practical purposes. The difference between the result found and the true velocity will be about the same amount for the same diameter as that shown in tables 7 and 8.

As shown above, the general form of the formulæ of D'Arcy and Kutter is

$$V=c\sqrt{r}\times\sqrt{s} \qquad (9)$$

$$\therefore\ c\sqrt{r}=\frac{V}{\sqrt{s}} \qquad (10)$$

$$\sqrt{s}=\frac{V}{c\sqrt{r}} \qquad (11)$$

$$S=\left(\frac{V}{c\sqrt{r}}\right)^2 \qquad (12)$$

Now

$$Q=a\,V=ac\sqrt{r}\times\sqrt{s} \qquad (13)$$

$$\therefore\ a=\frac{Q}{v} \qquad (14)$$

TABLE 4.—Giving fall in feet per mile; the distance corresponding to a fall of one foot, and also the values of s and $\sqrt{s}$.

$s=\frac{h}{l}$ = sine of slope = fall of water surface (h) in any distance (l) divided by that distance.

Fall in feet per mile.	Slope, one in	s	$\sqrt{s}$.
1	5280.	.000189393	.013762
2	2640.	.000378787	.019463
3	1760.	.000568182	.023836
4	1320.	.000757576	.027524
5	1056.	.000946969	.030773
6	880.0	.001136364	.033710
7	754.3	.001325797	.036411
8	660.0	.001515151	.038925
9	586.6	.001704445	.041286
10	528.0	.001893939	.043519
11	443.6	.002083333	.045643
12	440.0	.002272727	.047673
13	406.1	.002462121	.049620
14	377.1	.002651515	.051493
15	352.0	.002840909	.053300
16	330.0	.003030303	.055048
17	310.6	.003219696	.056742
18	293.3	.003409090	.058388
19	277.9	.003598484	.059988
20	264.0	.003787878	.061546
21	251.4	.003977272	.063066
22	240.0	.004166667	.064549
23	229.6	.004356060	.066000
24	220.0	.004545454	.067419
25	211.2	.004734848	.068810
26	203.1	.004924242	.070173
27	195.2	.005113636	.071510
28	188 6	.005303030	.072822
29	182.1	.005492424	.074111
30	176.0	.005681818	.075378
31	170.3	.005871219	.076624
32	165.0	.006060606	.077850
33	160.0	.006250000	.079057
34	155.3	.006439393	.080246
35	150.9	.006628788	.081417
36	146 6	.006818181	.082572
37	142.7	.007007575	.083711
38	139.0	.007196969	.084835
39	135.4	.007386363	.085944
40	132.0	.007575757	.087039
41	128.8	.007765151	.088120
42	125.7	.007954545	.089188
43	122.8	.008143939	.090244
44	120.0	.008333333	.091287
45	117.3	.008522727	.092319
46	114.8	.008712121	.093339
47	112.3	.008901515	.094348
48	110.0	.009090909	.095346
49	107.7	.009280303	.096334
50	105.6	.009469696	.097312
51	103.5	.009659090	.098281
52	101.5	.009848484	.099241
53	99.60	.010037871	.100189
54	97.77	.010227373	.101130
55	96.00	.010416667	.102060
56	94.28	.010606060	.102983
57	92.63	.010795454	.103901
58	91.03	.010984848	.104809
59	89.49	.011174242	.105708
60	88.00	.011363636	.106600
65	81.23	.012310606	.110953
70	75.43	.013257575	.115141
80	66.00	.015151515	.123091
90	58.66	.017045454	.130559
100	52.80	.018939393	.137620
120	44.00	.022727272	.150756
140	37.71	.026515151	.162835
160	33.00	.030303030	.174077
180	29.33	.034090909	.184637
200	26.40	.037878787	.194625
240	22.00	.041666667	.213200
280	18.86	.053030303	.230283
320	16.50	.060606060	.246183
360	14.66	.068181818	.261116
400	13.20	.075757575	.275241
450	11.73	.085227272	.291937
500	10.56	.094696969	.307729
600	8.800	.113636363	.337100
700	7.543	.132575757	.364109
800	6.660	.151515151	.389249
900	5.866	.170454545	.412861
1000	5.280	.189393939	.435194
1500	3.520	.284090909	.532925

$$ac\sqrt{r}=\frac{Q}{\sqrt{s}} \qquad (15)$$

$$\sqrt{s}=\frac{Q}{ac\sqrt{r}} \qquad (16)$$

$$\left(\frac{Q}{ac\sqrt{r}}\right) \qquad (17)$$

By the use of the tables of factors as applied to the solution of the six formulæ (9) (10) (11) (13) (15) (16) all the information relative to pipes, such as velocity, slope, etc., can be obtained.

Kutter gives for the values of the natural coefficient of surface :

n=.010 Plaster in pure cement.

n=.011 Plaster in cement with one-third sand.

n=.013 Ashlar and brickwork.

Mr. Lewis D'A. Jackson, C. E., who first translated the work of Kutter into English, and who in his *Hydraulic Manual*, and other contributions to the literature of hydraulic engineering, has done so much to introduce the new and improved hydraulic formulæ into English and American practice, extends the

range of surfaces to which the above values of n apply.

In his *Hydraulic Manual* he states that:

"A coefficient of roughness $n=.010$ has been assumed as applicable to glazed or enameled pipes, and one of .013 for ordinary metal or earthenware or stoneware pipes under ordinary conditions, but not new; and there is every reason to believe that these assumptions are generally correct; if we compare the smoothness of surface of a glazed pipe with that of very smooth plaster in cement, and that of an ordinary pipe, in average condition with that of ashlar or good brickwork; in addition to this, such few partial and limited experimental data as are available support the assumption."

Mr. R. Hering, C.E., in a paper read before the Am. Soc. C. E., in 1868, gave a list of pipes of different materials whose surfaces closely approximate in roughness to the surfaces included by Kutter's coefficients $n=.011$, and $n=.013$.

In this paper the coefficients of Jackson and Hering have been adopted, and table 2 gives $n=.011$ for surfaces carefully plastered with cement with one-third sand in good condition, also for iron, cement and terra-cotta pipes, well jointed, and in best order, and also surfaces of other material equally rough. Table 3 assumes that $n=.013$ for ashlar, well laid brickwork, ordinary metal, earthenware and stoneware pipes, but not new, cement and terra-cotta pipes not well jointed nor in perfect order, plaster and planed wood in imperfect or inferior condition, and also surfaces of other material equally rough.

In Table 5 the coefficients of D'Arcy, and Kutter with $n=.011$ for smooth pipes are placed in parallel columns for purposes of comparison. It will be seen that beginning with the small pipes D'Arcy's coefficients have, for the same diameter, a greater value than Kutter's, but that as the diameters increase, the value of the coefficients approach nearer to each other, until at 14 inches diameter they are equal. From this point as the diameter's increase, Kutter's coefficients are the greater, the difference increasing with the increased diameter of pipes. For diameters greater than 10 feet D'Arcy's coefficient is almost constant. It increases very little more than 113.5 even for a diameter of 16 feet or more, but Kutter's coefficient continues to increase until such a diameter is reached as is never likely to be required in practice.

Now, the experiments on which D'Arcy's formula is based were made on clean pipes, of the diameters usually adopted in practice, flowing under pressure and under conditions somewhat similar to pipes in actual use, and therefore, as the experiments were conducted with great accuracy, the results are entitled to the confidence of engineers. D'Arcy's experiments did not, however, include pipes of a very large hydraulic mean radius.

TABLE 5.—Comparison of coefficients (c) in the formula.

$$V=c\sqrt{rs}.$$

D'Arcy's coefficients for clean pipes under pressure.—Kutter's coefficients for pipes flowing full with $n=.011$ and $s=.001$.

Diameter. Ft.	Diameter. Ins.	D'Arcy's Coefficients for clean pipes.	Kutter's Co-efficient, $n=.011$ $s=.001$
0	5	103.8	82.9
0	6	105.3	87.4
0	7	106.4	91.5
0	8	107.2	95.0
0	9	107.9	97.9
0	10	108.5	100.5
0	11	108.9	103.3
1	0	109.3	105.7
1	2	109.9	109.5
1	4	110.4	113.0
1	6	110.7	116.2
1	8	111.0	118.8
1	10	111.3	121.3
2	0	111.5	123.6
2	3	111.7	126.5
2	6	111.9	129.1
2	9	112.1	131.5
3	0	112.2	133.6
3	3	112.3	135.6
3	6	112.4	137.2
3	9	112.5	138.8
4	0	112.6	140.4
4	3	112.7	141.7
4	6	112.7	143.0
5	0	112.8	145.4
5	6	112.9	147.6
6	0	113.0	149.5
6	6	113.0	151.2
7	0	113.1	152.7
8	0	113 2	155.4
9	0	113.2	157.7
10	0	113.3	159.7

TABLE 6.—Of coefficients (c) from the formulæ of D'Arcy, Kutter and Fanning for small pipes below 5 inches in diameter.

$$V = c\sqrt{rs}.$$

Diameter in inches	(c) D'Arcy's Co-efficient for clean pipes.	(c) Kutter's Co-efficient from formula n=.011 s=.001	(c) Kutter's Co-efficient recommended by L. D. A. Jackson.	(c) Fanning's Co-efficient for clean iron pipes.
0	59.4	32.0	82.9	
$\frac{3}{8}$	65.7	36.1	82.9	
$\frac{1}{2}$	74.5	42.6	82.9	
$\frac{3}{4}$	80.4	47.4	82.9	80.4
1	84.8	51.9	82.9	
$1\frac{1}{4}$	88.1	55.4	82.9	88.0
$1\frac{1}{2}$	90.7	58.8	82.9	92.5
2	92.9	61.5	82.9	94.8
$2\frac{1}{2}$	96.1	66.0	82.9	
3	98.5	70.1	82.9	96.6
4	101.7	77.4	82.9	103.4
5	103.8	82.9	82.9	

TABLE. 7—Showing the velocity in feet per second in pipes, by Kutter's formula (6) and also by the tables, the value of n being .011.

Diameter, Feet.	Inches.	Slope, one in	Velocity, by Kutter's formula.	Velocity, by Flynn's tables.
1	0	66	6.62	6.51
1	0	2640	1.02	1.03
2	0	66	10.89	10.75
2	0	2640	1.67	1.70
4	0	66	17.52	17.28
4	0	2640	2.70	2.73
6	0	66	22.63	22.54
6	0	2640	3.54	3.56

TABLE 8.—Showing the velocity in feet per second in pipes, by Kutter's formula (6) and also by the tables, the value of n being .013.

Diameter, Feet.	Inches	Slope, one in	Velocity, by Kutter's formula.	Velocity, by Flynn's tables.
1	0	66	5.34	5.25
1	0	2640	0.81	0.83
2	0	66	8.91	8.80
2	0	2640	1.36	1.39
4	0	66	14.44	14.34
4	0	2640	2.24	2.27
6	0	66	18.91	18.82
6	0	2640	2.94	2.98

Kutter's formula is derived not only from experiments made on channels with small hydraulic radius, but also on channels with large hydraulic radius, and his coefficients for very large pipes are therefore more likely to agree with the actual discharge than D'Arcy's constant coefficient of 113.5 for very large pipes. But again, Kutter's formula is open to the objection that it is based on experiments made on open channels. I may here remark, although it is only remotely connected with pipe discharge, that Major Allan Cunningham states, as the result of his extensive experiments for four years on the Ganges Canal, that Kutter's formula alone, of all those tried by him, was found generally applicable to all conditions of discharge, and that it gave nearer results to the actual velocity than any of the other formulæ tried by him. It gave results with a difference from the actual velocity seldom exceeding $7\frac{1}{2}$ per cent., and usually much less than that. When we contrast the wide divergence of the old formulæ under varying flow from the actual velocity, with the results obtained by Kutter's formula, it will be seen that the latter is the most accurate formula for channels with large hydraulic mean radius.

In Tables 2 and 3 the values of the factors of Kutter's formula are not given for diameters less than 5 inches. Mr. L. D'A. Jackson, C. E., in his *Hydraulic Manual*, states:

"For the present, and until further experiments have thrown more light on the subject, it may be assumed that the coefficient of discharge for all full cylindrical pipes, having a diameter less than 0.4 feet, will be the same as those of that diameter."

Although Mr. Jackson's opinion is entitled to great weight, still the facts all tend to prove that the coefficients of diameters below 5 inches should diminish with the diminution of diameter. The smaller the diameter the more effect will the roughness of the surface have in diminishing the discharge. Table 5 shows that Kutter's coefficient for 5 inches diameter with n=.011 is 82.9, and therefore, according to Mr. Jackson, all the diameters from 5 inches to $\frac{3}{8}$ inch should have a coefficient of 82.9. This is contrary to the principle of Kutter's formula, the accuracy of which is due to

the fact that, other things being equal, its coefficients vary with the diameter. The following proofs are given in support of the opinion that coefficients of diameters below 5 inches should diminish according to the diminution of diameter.

1. In Table 6 the coefficients of D'Arcy's formula are seen to diminish. At 5 inches diameter the coefficient is 103.8, and at $\frac{3}{8}$ inch diameter 59.4.

2. In Table 6 the coefficients of Fanning's formula diminish from 4 inches diameter with a coefficient of 103.4 to one inch diameter with a coefficient of 80.4.

These coefficients are derived from the mean velocities in clean pipes with a slope of 1 in 125 given in Fanning's tables.

3. In Table 6 the coefficients, as found by Kutter's formula with a slope of 1 in 1,000, and $n=.011$, are for 5 inches diameter, 82.9, and for $\frac{3}{8}$ inch diameter, 32.0.

The facts, therefore, show that the coefficients diminish from a diameter of 5 inches to smaller diameters, and it is a safer plan to adopt coefficients varying with the diameter than a constant coefficient. No opinion is advanced as to what coefficients should be used with Kutter's formula for small diameters. The facts are simply stated, giving the results of well-known authors.

As the coefficients of D'Arcy's formula vary only with the diameter, the values of the factors $c\sqrt{r}$ and $a\,c\sqrt{r}$ given in Table 1 for D'Arcy's formula are practically the exact values for all diameters and slopes given, and the results found by the use of the tables will be the same as the results found by using the formula.

Kutters factors as given in the tables, are, however, absolutely exact for only one slope, that of 1 in 1,000; but for the slopes given in actual practice to pipes, sewers, conduits, etc., the use of the factors gives results differing so little from the results derived from the use of the complicated formula (6) that the values of the factors $c\sqrt{r}$ and $ac\sqrt{r}$ given in the tables may, for all practical purposes, be accepted as sufficiently accurate.

In tables 2 and 3 the values of $c\sqrt{r}$ and $a\,c\sqrt{r}$ for Kutter's formula differ by a small quantity from the actual values as found by the use of formula (6). These values by Kutter's formula depend not only on r, but also on n and s, so that a change in any of these three quantities causes a change in the values of $c\sqrt{r}$ and $a\,c\sqrt{r}$. It is found, however, that the slope of 1 in 1,000 will give coefficients which practically differ very little from the coefficients derived from the slopes usually given to lines of pipe.

The values of the coefficients from Kutter's formula given in the tables have been computed for a slope of 1 in 1,000, and they give values of $c\sqrt{r}$ and $a\,c\sqrt{r}$ near enough for practical work.

The two tables 7 and 8 show how small is the difference between the velocity found by the tables of factors and the velocity found by formula (6). The difference seldom reaches more than three per cent., and it is generally less than one per cent. In most cases this degree of accuracy will be deemed sufficient, but should the engineer prefer to use formula (6), even then the tables of factors will give a ready means of checking the computations.

EXPLANATION AND USE OF THE TABLES.

The velocity mentioned below means velocity in feet per second. The discharge mentioned below means the discharge in cubic feet per second.

1. What is the velocity and discharge by Kutter's formula of an iron pipe of 2 feet diameter, and with a fall of 9 feet per mile, the value of n being assumed equal to .013.

By formula (9) $V=c\sqrt{r}\times\sqrt{s}$
and by formula (13) $Q=ac\sqrt{r}\times\sqrt{s}$

In Table 4 look out the value of $\sqrt{s}$ corresponding to a fall of 9 feet per mile, and it is found $=.041286$. Look out also in Table 3 the value of $c\sqrt{r}$ and $ac\sqrt{r}$ opposite a diameter of 2 feet, and they will be found to be respectively equal to 71.49 and 224.63—substituting the values so found in equations (9) and (13), and we have

$V = 71.49 \times .041286 = 2.95$ feet per second velocity.

$Q=224.63\times.041286=9.27$ c. feet per second discharge.

If the velocity and discharge are found by Kutter's formula (6) it will be seen that a very great saving of work is effected by the use of the tables.

2. An iron pipe one foot six inches in diameter, whose natural coefficient of roughness is assumed =.011, is to have a velocity not to exceed 3 feet per second. What should its slope be by the use of Kutter's formula?

By formula (11)

$$\sqrt{s} = \frac{V}{c\sqrt{r}}$$

Find by inspection in Table 2 the value of $c\sqrt{r}$ opposite 1 foot 6 inches. It is equal to 71.08. Substitute this value and also the given velocity in equation (11) and we have

$$\sqrt{s} = \frac{3}{71.08} = .042206$$

Look out the nearest value of $\sqrt{s}$ to this in Table 4, and it will be found to be .043419 opposite a slope of 10 feet per mile, which is the slope required.

3. A 3 feet 6 inch old iron pipe whose natural coefficient is assumed = .013 is to be replaced by a new pipe capable of discharging double that of the old pipe, the slope remaining unchanged. What is the diameter by Kutter's formula of the new pipe, its natural coefficient being assumed=.011.

Find by inspection in Table 3 the value of $ac\sqrt{r}$ opposite 3 feet 6 inches diameter. It is found equal to 1021.1. Then $1021.1 \times 2 = 2042.2$. As the value of n for the new pipe = .011, look out in Table 2 the value of $ac\sqrt{r}$ nearest to 2042.2, and it is found to be 2072.7 opposite a diameter of 4 feet 3 inches, which is the diameter required.

Look up the values of $c\sqrt{r}$ for each pipe, and it will be seen that the velocity in the new pipe is to that in the old as 146 : 106.

4. This example is taken from Weisbach's *Mechanics of Engineering*.

A system of pipes consisting of one main and two branches is required to discharge by one branch 15, and by another 24 cubic feet of water per minute. The levels show the main pipe to have a fall of 4 feet in 1,000, the first branch 3 feet in 600, and the other branch 1 foot in 200. What diameter should the pipes have?

For the solution of this example table 1, derived from D'Arcy's formula, will be used.

The main is to discharge 39 cubic feet per minute, equal to 0.65 cubic feet per second with a slope of 1 in 250. One branch 15 cubic feet per minute, equal to 0.25 cubic feet per second, with a fall of 1 in 200, and the other branch, 24 cubic feet per minute = 0.4 cubic feet per second, with a fall of 1 in 200.

By inspection find in Table 4 the value of $\sqrt{s}$ nearest to 1 in 250 (21 feet per mile) and it is found to be=.063066, and also find the value of $\sqrt{s}$ nearest to 1 in 200 (26 feet per mile). It is found = .070173. By formula (15).

$$ac\sqrt{r} = \frac{Q}{\sqrt{s}}$$

$\therefore$ for main pipe $ac\sqrt{r} = \frac{0.65}{.063066} = 10.307$

the nearest value of $ac\sqrt{r}$ to this in Table 1 is 10.852, opposite which is the diameter, 7 inches.

In the same manner for the first branch,

$$ac\sqrt{r} = \frac{0.25}{.070173} = 3.562$$

and the nearest value of $ac\sqrt{r}$ to this, in Table 1, is 4.561, corresponding to a diameter of 5 inches.

For the second branch,

$$ac\sqrt{r} = \frac{0.4}{.070173} = 5.7$$

and the nearest value of $ac\sqrt{r}$ to this, in Table 1, is 7.3 opposite a diameter of 6 inches. The required diameters are therefore: for the main pipe 7 inches, for the first branch 5 inches, and for the second branch 6 inches.

Although the explanation of this example, in the use of the tables may appear somewhat long, still the actual work can be done very rapidly and with little trouble. If a comparison is made of the work required for the solution of this example, as given above by the tables, with the work required for its solution by the method of approximation as given in Weisbach's *Mechanics of Engineering*, from which the example is extracted, it will be seen that there is a great saving of labor effected by the use of the tables.

A more extensive table of slopes and $\sqrt{s}$ than Table 4, and also table of factors for circular and egg-shaped brick sewers with $n=.015$ are given in "Hydraulic Tables" in No. 67 of *Van Nostrand's Science Series* by the writer of this paper.

[No. 67 of Van Nostrand's Science Series contains similar tables for circular and egg-shaped sewers.]

PROOF TESTS OF IRON AND STEEL.

From "The Engineer."

THE extent to which iron or steel should be strained by testing it, when made up into a boiler, a small girder, a bolt, &c., has from time to time formed matter for debate amongst the most competent experts for a very long period, and still remains so to some extent, although a sort of general agreement has been arrived at that the test stress ought not to be less than one-third or more than one-half the ultimate strength of the *matériel*. Cases occur now and then, however, where a member of a structure tested before fitting in place to half the estimated ultimate strength, fails soon after it is put to work at, at all events, an estimated stress much below that to which it was exposed in testing. Such cases, though comparatively rare, cause, when they occur, perplexity in the minds of engineers, and shake their faith in the utility of proof tests. Such tests, in common with many other sources of information on things mundane, are valuable in proportion to the intelligence and soundness of judgment with which their results are considered. Because the subsequent behavior of the material tested may, in stray instances, contradict the testimony of the test, it should not be concluded that tests are therefore altogether valueless. Such tests are of the highest importance, and much of the research devoted to the investigation of the chemistry, the molecular formation, and the effects of working upon iron and steel, has been brought about not only by the results of tests, but also by even the contradictions apparently visible about such tests. To paraphrase Euclid, conditions cannot be the same and yet be different one from another; and it is owing to the operation of this law that many of the seeming contradictions shown between the behavior of iron in the testing machine and its subsequent performance in actual work are really, when intelligently considered, no contradictions at all. Theory is one thing, practice another—very much another frequently. The trial of a piece of iron or steel in a machine made with mathematical precision, the piece itself prepared with the greatest care, and the strain applied under very special conditions, constitutes, perhaps, the nearest known approach of practice to theory. The iron from which the sample has been taken is probably most identical in quality with it, yet when worked into a girder, a crane jib, the rib or stringer of a ship, or other structure, it fails at what seems to be a much lower stress than should have sufficed to fracture it, simply because at the time other conditions are present.

The real value of proof tests, as dealt with in commercial transactions or engineering work, is two-fold. First, they enable the engineer, by the process of analogous reasoning, to estimate chances pretty closely; to calculate from past experience even of the percentage of seemingly inexplicable failures, and to specify for a particular class of metal. He may specify on either of two systems—he may stipulate that certain mixtures of ores are to be used, that they are to be worked with certain fuel, and in a particular way, knowing by experience that a certain process of manufacture will give material of corresponding nature; or he may take the simple course of demanding material that shall endure a certain proof strain. Unless the engineer be what many otherwise eminent men are not, an expert practical iron worker by training, it is best for him to adopt the latter course; the adage that "a little knowledge is a

dangerous thing" is essentially applicable to iron or steel making. Those who mean to make good iron must devote all their time to the study of that subject alone. If an imperfectly informed person draw a specification stating a particular method of making his iron, and that it disappoints his expectations when brought to the testing machine, he cannot blame any but himself, he must abide by his bargain. Having taken the premises of the transaction into his own hands, obviously he must stand or fall by the results. Where he leaves the premises to the iron maker, simply demanding a certain result, the maker has to bear the risks.

The second use of tests is really to enable business to be done at all. We have not yet reached the stage where the iron maker is called on to warrant the working endurance—the life insurance in effect—of the stuff embodied in a roof, bridge, or ship, steam boiler, or railway axle. Perhaps, by-and bye, a system of life insurance, at least for railway axles, whether plain or cranked, may come into practice, and its introduction might have good results; but all that is in the future. If an engineer wants iron, it is obvious that some intelligible and simple definition of quality must be used, and the subsequent behavior of the material is another matter. The real point for the users of iron or steel to consider is how best to prolong the life of either; and the method in which either is called upon to perform its work enters as intimately into the question as do the laws of health and sanitation into that of the duration of animal existence. Iron will, it may be almost certainly assumed, have a very prolonged life if exposed to statical strains alone well within its elastic resistance. In a long-continued state of repose under stress it perhaps gradually becomes crystalline, but with nothing like the same rapidity as when exposed to vibration. That the natural tendency of iron is to pass from a fibrous to a crystalline state is well known, and the process of transition is rapid in proportion to the amount of vibration brought to bear upon it. Fairbairn's famous experiments on rods and bars exposed to exceedingly moderate stress while at the same time struck rapidly by a revolving cam, with the resulting speedy fracture of the bars, are familiar to most men who have given any thought or attention to the subject. These experiments are borne out every day, especially on railways.

In order to remedy a defect its cause must first be sought. We will take axles of railway wagons and propeller shafts as two examples. In both these examples we have vibration attending on their use, though different in nature; in the axle the vibrations are short, sharp, and incessant, in kind not very unlike that caused by Fairbairn's cams; the result is also the same, though longer deferred. In respect to securing the endurance of axles, two parties are obviously concerned—the maker of the material and the user of the axle—and both are responsible in the matter. We must candidly express the opinion that the axle makers have done far more to give the public immunity from accidents due to broken axles than have axle users. Of the two horses drawing the coach, one does, we will not say more than his share; he does his utmost, however, and no stone is left unturned, no expense spared, no device neglected by our iron and steel makers, to produce unbreakable axles; but we may, and do say, that axle users, and especially private wagon owners, have done nothing on their side of the pole to draw the coach. Wagon axles are fitted now as they were forty years since; no attempt at improvement, no effort to diminish vibration has been, or is being, made. The springs, the only deadeners of shock attempted to be used, are little better than a name. They are too rigid. They do not possess enough elasticity to be long-lived even themselves, and their preservative influence upon axles is almost *nil*. What we have said of axles applies equally to propeller shafts. Makers of these use every effort to produce sound shafts, but marine engineers, like railway men, stir not to improve the conditions of the workings of these shafts. Railway men, indeed, go through the form of introducing shock deadeners, but marine engineers do not even this; and it is idle to make tests, obtain certain material, and then put that material to work under conditions that daily experiences prove to be faulty in the extreme.

YACHT MEASUREMENT AND TIME ALLOWANCE.

From the "Nautical Magazine."

DURING the past winter, the question of time allowance for yachts has been again under the consideration of the Yacht Racing Association, and a step has been taken by them which it is hoped may promote competitions between cruising yachts and racers. The developments of the last few years, it has been pretty generally admitted, have had a prejudicial effect upon sport. Competitions, it is said, are practically limited to the latest-built racing machines, which cost very large sums of money, have poor accommodation, and are only adapted to win cups for a few seasons, after which they are out of date as racers and not fit for cruisers. It has been sought to adopt some principle of distinction by which racers and cruisers might compete on something like equal terms; but, of course, the old difficulty has cropped up, and it is first necessary to establish some rule by which to determine what is a racer and what a cruiser. There is, further, the class of yachts to be considered which may be called ex-racers, and whose capabilities for winning prizes are of an intermediate character. The Association have decided upon a scheme for the classing of yachts in three divisions, called A, B, and C, in which for purposes of racing, class A would be rated at four times their tonnage, class B at twice their tonnage, and class C at their nominal tonnage. The means of distinguishing between the classes is by sail area, or rather, by the area of the mainsail and topsail. A maximum area is prescribed for classes B and C, but of course in A it is unlimited. It is not expected that this will be of very much benefit to old-fashioned cruisers, but it will, certainly, where it is carried out, give an opportunity for ex-racers to compete on equal terms with racers of the present type. It will be remembered that the tonnage rule of the Yacht Racing Association is

$$\frac{(\text{Length and Breadth})^2 \times \text{Breadth}}{1730}$$

but an alternative measurement is based upon sail area as follows:

$$\frac{\text{sail area} \times \text{Length}}{7000}$$

It would appear that where the latter rule be adopted, in combination with the new classification, the racers will, through having to pay a double price for their large sail area, be at a considerable disadvantage in comparison with vessels in class B. There is every probability that this new arrangement will enlarge the area of competition, and so promote genuine sport, but it will have this distinct disadvantage that vessels in classes B and C will not be able to use the sails which are suited to their size and stability, but will have to adopt, where possible, just about the area allowed them as their maximum. It is, however, absolutely impossible to place all vessels on an equal footing for racing, and, if this could be done, it would not, we think, promote the interest of genuine sport. If we could measure every point which makes for speed, assess it, and then give time allowance for the whole, yacht racing would become merely a trial of skill in sailing, not what it should be—a competition between yachts.

In an able paper, read before the Institution of Naval Architects, at their recent session, Captain Tuxen has attempted to do this, but we do not think, for the reasons stated above, that his, or any similar proposal, is likely to find much favor with yachtsmen. Captain Tuxen, it should be stated, is Chief Constructor of the Danish Royal Navy, and was a student at the Greenwich School of Naval Architecture. He has been induced to turn his attention to the subject by request from a Copenhagen Yacht Club. Captain Tuxen's scheme is thus stated by himself:—

(1). The dimensions to be taxed are L, length of water-line (with probably some addition for yachts with excessive rake of stem and counter); B, largest breadth; H, draught of water.

(2). Of the total sailing power which a yacht possesses, a certain percentage is due to her length, a certain percentage

to her breadth, and the remainder is due to her draught.

(3). The three dimensions are to be taxed the same relative proportion as their influence upon the sailing power of the yacht.

(4). By increasing any one of the dimensions the tonnage of the yacht is to increase proportionally to the increase of that part of her sailing power which is due to this dimension.

To satisfy these requirements the following system is worked out, viz. :—

$$\text{Yacht tonnage} = \frac{C_1 L^3 + C_2 B^3 + C_3 H^3 + C_4 L + B + H.}{C_5.}$$

The coefficients C_1 to C_5 have to be determined so that the above conditions are satisfied, and should this not be possible more terms must be added, but no doubt it will be found that the number given is sufficient. The coefficients have been determined to suit several yachts of great variety of form which have sailed so much together that their relative sailing power is known, and the following result has been obtained :—

$$\text{Yacht tonnage} = \frac{L^3 + 10\,B^3 + 30\,H^3 + 20\,L + B + H.}{11000.}$$

The following table shows the relative influence of the three dimensions on the sailing power of some different forms of yachts according to this system :—

Proportions of Yacht. L.	B.	H.	Perc'tage of sail'g power due to: Length.	Breadth.	Draught.
1 ..	$\frac{1}{3}$ ..	$\frac{1}{4}$	56.5 ..	28.5 ..	16.
1 ..	$\frac{1}{4}$ ..	$\frac{1}{6}$	60 ..	20.5 ..	19.5
1 ..	$\frac{1}{6}$ ..	$\frac{1}{8}$	63 ..	13.5 ..	23.5

If this system should be adopted in any place, and should be found not to tax the three dimensions according to the experience at that place, the coefficients are easily altered. If any dimension is found to be taxed too severely, the corresponding coefficient has to be diminished, and *vice versa*. If extreme proportions of yachts are found to be taxed too much, the coefficient of the fourth term has to be increased, and *vice versa*.

Captain Tuxen's rule it will be seen, is an attempt to make such allowances as will bring all yachts on an equality, both as regards sailing power and also resistance, in fact, as we have said, if his rule were successful in its operation, yacht races would be reduced to competitions between sailing masters. What then is it advisable to measure in a yacht? If power, her stability would be the best measure on which to base time allowance. A rule of this character was suggested by Mr. Dixon Kempt in the *Field* of 11th of February, 1882. He proposed that the yacht should be inclined as ships are to find the center of gravity. The yacht should be in the condition in which she was to race with all weights in their proper places. Then if a weight W be moved across the deck through a distance k and the angle of inclination, thus produced, noted, which call A, then the formula for sail power will be :—

$$W \times k \times \text{contangent A}.$$

He proposed to multiply this quantity by the length and to divide by some appropriate divisor, say 300, to reduce the figures to something like actual tonnage.

Another measurement based upon power of propulsion, is the sail-area multiplied by length, which we have already spoken of as the alternative rule of the Yacht Racing Association. The chief disadvantage attending it is that it attaches equal importance to all the sails, whereas the mainsail is decidedly of much greater relative importance than is due to its excess in area.

The existing tonnage rule of the Association is based on dimensions; we have before expressed the opinion in these pages that its chief fault is the leaving draught of water out of the calculation. When half of two-thirds of the total weight of a yacht is ballast, the depth of that ballast is a most important factor, and a rule which leaves depth, or rather draught, out of the question, is, as a well-known yachtsman said in the *Field* a few months ago, like a bushel measure with no bottom to it. It has appeared to us that a rule like the old Thames rule but in which instead of half-breadth, draught should be used, in fact for

$$\frac{(L - B) \times B \times \frac{B}{2}}{94}$$

substitute

$$\frac{L \times B \times \text{Draught}}{100}$$

would be a fair measure of size, but if it be thought that length is relatively of

greater importance than the other dimensions it might take the form of

$$\frac{L \frac{3}{2} \times (B \times D) \frac{3}{4}}{C.}$$

where C is a constant divisor to be ascertained.

Captain Tuxen, in his paper, also deals with the question of time allowance, and, remarking that experience shows that a smaller yacht is by the present system taxed too severely relatively to a larger one when there is a strong wind, and too little when there is a slight wind, suggests that the principles regulating allowance should be:—

(1). The allowance of time given by a larger to a smaller yacht should be directly proportional to the distance sailed and the velocity of the wind, and inversely proportional to the size of the yachts.

(2). It is supposed that a yacht double the size of another can allow the latter 2.6 seconds per knot sailed through, and per knot velocity of wind.

He proposes to measure the average velocity of the wind during the time of the course by an anemometer, and gives a table for use in applying his principles of allowance. We do not think that yachtsmen are likely to favor any allowance for wind, that being an element of chance which gives zest to the sport. Beside this, it would be very difficult to measure by an anemometer the velocity of the wind *where the yachts were sailing*, while at a station on shore it might be altogether different. We may remark, in reference to this part of the question, that the Association has had the time-scale under consideration, and has determined upon an alteration with a view to decrease the allowance somewhat between large yachts and increase the allowance between small yachts.

ON THE ELECTROMOTIVE ACTION OF ILLUMINATED SELENIUM, DISCOVERED BY MR. FRITTS, OF NEW YORK.*

By WERNER SIEMENS.

From "The Electrical World."

Mr. Ch. E. Fritts, of New York, sent me, early last year, a description of his method of constructing light-sensitive selenium plates, differing from mine in essential features, and accompanied the same by a number of the plates prepared by him. These do not consist of parallel platinum wires embedded in a thin body of selenium, like mine,† but of a thin, homogeneous sheet of selenium, which is spread upon a metal plate, and after a subsequent heating—for the conversion of the amorphous into crystalline selenium—is covered over with a fine gold leaf. Mr. Fritts has found that the green light which penetrates through the gold, by the further passage through the selenium heightens its electrical light-capacity. In fact the sensitiveness to light (electrical conductivity) of the selenium plate between the gold leaf and the metallic base-plate is increased by the lighting of the gold leaf with direct sunlight falling perpendicularly upon it, in some of the constructions sent here, from 20 to 200 times! The effect of the illumination by diffused daylight is also greater in the Fritts cells than in mine.

One of the plates sent over to me showed absolutely no sensitiveness to light, but in place of that it has a different and most noteworthy property (*hochst merkwurdige Eigenschaft*), namely, that when a galvanometer is inserted between the gold leaf and the base-plate it shows an electrical current in the direction of the light action through the selenium, which continues as long as the gold leaf is illuminated. I conjectured at first that this current was not lasting, but had the character of a polarization current, which continued only until the molecular modification of the selenium by the illumination was completed, and a first experiment seemed to confirm this supposition.

* Read by the author before the Berlin Academy of Sciences on Feb. 12, 1885.

† *Monatsbericht der Berl. Akad. d. W. vom* 13. *Mai* 1875 *und* 7. *Juni* 1877.

But further trials convinced me that this idea was erroneous. In reality, we have here to do with an entirely new physical phenomenon, which is scientifically of the most far-reaching importance (*die von grosster wissenschaftlicher Tragweite ist*).

My experiments show that by the illumination of the gold leaf a difference of potential is established between it and the base-plate, which, to all appearance, is proportional to the intensity of the light, and which stands forth unchanged so long as the illumination remains constant. Obscure heat radiations do not produce electromotive force, and therefore the supposition of a thermo-electric action as the explanation of the phenomenon is excluded. Mr. Fritts holds that the light-waves penetrating the selenium are converted directly into electrical current, and therefore states as the fact the proportionality of the strength of the current to the strength of the light. They showed themselves nearly so, in the collated series of trials given in the following table:

Strength of the light in standard candles	6.4	9.9	12.8	16.8
Strength of the current	18.0	30.0	40.0	48.0
Quotient	2.8	3.0	3.1	2.8

The strength of the light was measured with a Bunsen's photometer; that of the current by the deflections of a sensitive mirror galvanometer.

With the gold leaf exposed to the light from the south-eastern portion of a cloudless sky, while the sun itself was hidden by the neigboring high buildings, the series of measurements in the following table were obtained:

Time of observation	9.37	10.05	10.30	11.00	11.35	12.00	12.30
Deflections of the galvanometer	190	196	209	223	250	250	244
Time of observation	1.00	1.30	2.00	2.30	3.00	3.30	4.00
Deflections of the galvanometer	245	349	228	188	173	172	108

It is seen from the foregoing that the electromotive force of the selenium pretty uniformly increased from 9.30 A. M. until 11.35 A. M., the current then remained almost constant during two hours, and thereafter again quite uniformly decreased till 3.00 P. M.

As to the reason why some of his selenium plates become more conductive during illumination, while others produce electromotive force, Mr. Fritts has no explanation to give. He complains of the uncertainty in the preparation of the plates, of whose property one can foresee nothing, and gives various manipulations by which one can often render unserviceable plates useful. There is yet required thorough investigation to determine upon what the electromotive light-action of many selenium plates depends. Nevertheless, the existence already of a selenium plate with the property described is a fact of the greatest scientific significance, since there is here presented to us, for the first time, the direct conversion of the energy of light into electrical energy (*eine Thatsache von grosster wissenschaftlicher Bedeutung, da uns hier zum ersten Male die directe Umwandlung der Energie des Lichtes in elektrische Energie entgegentritt*).

Note.—The uncertainties, etc., mentioned by Dr. Siemens as existing at the time I wrote the communication referred to (in February, 1884) have since been largely overcome. I have conclusively determined the conditions upon which the electromotive light action depends, and with more complete and perfect apparatus for preparing the plates, I believe that I can even now effect the conversion of more than 50 per cent. of the energy of light into electrical energy. If my theory proves to be complete, when fully carried out and tested in all its variations, we may ere long see the photo-electric plate competing with the dynamo-electric machine itself in high percentage of electrical conversion. In compactness, it is not designed to compete with it, being adapted and intended principally for what is known as "isolated" working—*i. e.*, for each building to have its own plant.

I am now able to foresee the general properties of the plates, and to give them such of the properties as I wish. I can cause a plate to show either an electromotive action or a higher conductivity when exposed to light, or to show both properties. In explanation of the slight irregularity in the action of the electromotive plate measured by Dr. Siemens, it should be stated that it was not prepared for that purpose, but was sent to him as exhibiting another and entirely different property. During the development of that property it had received some of the manipulations adapted for giving the electromotive action, and in consequence thereof it could generate a slight current upon exposure to light, although not with

the uniformity of a specially prepared electromotive plate. It will also be noted that "the south-eastern portion of a sky without clouds" (direct sunlight being excluded) is not a very intense source of illumination. But this fact renders the trial more satisfactory.

At the time of sending him the samples of my different constructions, I had not a very large number of the electro-motive plates, and they were in almost daily use in experiments from which to deduce the philosophy of the action, so that they could not be spared, and I contented myself with pointing out that the plate in question could generate a current, sufficient, at least, to prove its possession of that property. After having my papers, data and plates under consideration nearly a year, Dr. Siemens, than whom there is no higher or better authority, has accorded to me the honor of being the first one to produce electricity directly from light.

But I do not explain the action exactly as he supposes—that "the light-waves are converted directly into electrical current"—as is shown by the following statement concerning it, in my paper on "Selenium," read before the American Association for the Advancement of Science, at Philadelphia, Sept. 5, 1884: "The light * * passes through the gold and acts upon its junction with the selenium, developing an electromotive force which results in a current," when the circuit is completed. "The current thus produced is radiant energy converted into electrical energy directly and without chemical action." The final result is the same, of course, but the *rationale* is different.

In conclusion, I would say that however great the scientific importance of this discovery may be, its practical value will be no less obvious when we reflect that the supply of solar energy is both without limit and without cost, and that it will continue to pour down upon us for countless ages after all the coal deposits of the earth have been exhausted and forgotten.

REPORTS OF ENGINEERING SOCIETIES.

AMERICAN SOCIETY OF CIVIL ENGINEERS—ANNUAL CONVENTION OF 1885.—The annual convention of this Society for the year 1885 will be held at Deer Park, Md., on the line of the Baltimore and Ohio Railroad, June 24th, 25th, 26th and 27th, 1885. Sessions for professional discussion and one for the transaction of business will be held.

By invitation of the officers of the Baltimore and Ohio Railroad Company, a steamer excursion will be made by members and their families on Monday afternoon, June 22d, to the Water Front of the Harbor of Baltimore, the marine terminals of the B. & O. R. R., Locust Point, Canton, Fort Carroll, Fort McHenry, and Curtis Bay, returning to Baltimore early in the evening.

Members and their families are invited to visit the summer evening concert, at the Baltimore Academy of Music, on Monday evening, under the escort of the Local Committee of Members of the Society and officers of the Baltimore and Ohio Railroad. This committee will have charge of all arrangements at Baltimore.

The sessions will be held during Wednesday, Thursday, Friday and Saturday, except that on one of those days, to be specially announced hereafter, an excursion will be made by invitation of the B. and O. R. R. to the Cheat River Grade, Kingwood Tunnel, Tray Run Viaduct, and other interesting points on the Mountain Division of the road.

ENGINEERS' CLUB OF PHILADELPHIA—RECORD OF MEETING, APRIL 18TH.—The following resolution, offered by Prof. L. M. Haupt, was unanimously adopted: That a committee be appointed to draft a memorial to the Legislature in behalf of the proposed topographical survey of this State, and to report at the next meeting.

A handsome framed engraving of the old Wernwag Bridge was presented to the Club.

This structure was designed and built by Louis Wernwag across the Schuylkill River, at Fairmount. The corner-stone was laid with Masonic ceremonies, April 28th, 1812. It was a wooden structure, with the bottom member arched—340 feet span, 20 feet rise. There were 5 trusses. The span was 98 feet greater than any other in the world at that time. Each truss was an open-built beam, formed of a bottom-curved solid-built beam and of a single top beam, which were connected by radial pieces, diagonal braces, and inclined iron stays. The bottom curved beam was composed of three concentric solid-built beams, slightly separated from each other, each of which had seven courses of curved scantling in it, each course 6 inches thick by 13 inches in breadth, the courses, as well as the concentric beams, being firmly united by iron bolts, etc. A roadway that rested upon the bottom curved ribs was left on each side of the center truss, and a foot-path between each of the two exterior trusses.

Mr. James F. Wood described the sewerage work now in progress at Atlantic City, N. J. The sewers are being laid, under contract, by Messrs. Robinson & Wallace, of New York, who expect to lay this year 600 feet of 24-inch pipe, 1,260 feet of 20-inch, and 4,000 feet of 15-inch, with their 6-inch connections.

Mr. Jones Wister presented a description of the Beaumont Rock Drill, which is said to bore

a 7-foot 2-inch hole at the rate of from 42 to 120 feet per week; to be suited to all rocks but the very hardest, and to avoid the leakage and foul air incident to the use of dynamite.

The workings of the drill were discussed by several members.

RECORD OF MEETING MAY 2D, 1885.—Prof. L. M. Haupt, chairman of committee appointed at last meeting to prepare a memorial to the Legislature of Pennsylvania, upon the continuation of the second geological survey of the State, presented the following report from that committee:

To the Honorable Lieutenant-Governor Chauncey F. Black, President, and the Honorable Amos H. Mylin, President, *pro tem*, of the Senate, and the Hon. James L. Graham, Speaker of the House of Representatives of Pennsylvania:

Whereas, The Engineers' Club of Philadelphia recognize the gross errors and discrepancies which exist in all of the best maps which have been constructed of Pennsylvania and of individual counties in the State, which have been published since 1816, and which are based upon Melish's State Map, constructed under authority of the Legislature of that year; and

Whereas, There is a great demand among those citizens of the State interested in all surface improvements and in the development of the natural resources of the State, for an accurate map, which shall establish the true geographical position of every point on its surface, north and south and east and west from every other point, and the elevation of all points above tide, so that the citizens of the commonwealth shall have correct maps of their respective townships and counties on which surface improvements may be outlined, and upon which surveyors can place land lines, and mining engineers and geologists can trace mineral outcrops and areas; and

Whereas, The Board of Commissioners of the Geological Survey have entered into negotiations with the United States Geological Survey, and the United States Coast and Geodetic Survey, and a plan of co-operation has been proposed by which the United States Surveys will expend in the State, for a geographical and topographical survey, $35,000 a year, if the State will expend $10,000 a year, and which co-operation now depends upon the granting of a State appropriation by the Legislature in accordance with the recommendations of the Board of Commissioners; and

Whereas, Such State maps are now being constructed by New York, Massachusetts and New Jersey, it is, therefore,

Resolved, By the Engineers' Club of Philadelphia, that they respectfully petition your Honorable bodies to speedily pass House Bill 497, entitled "An Act to provide for the continuance of the Geological Survey of the State," as originally introduced and committed to the Appropriation Committee of the House of Representatives, wherein an appropriation of $90,000 is asked, $20,000 of which provides for the continuance of topographical work and the commencement of the construction of an accurate map of the State, and your petitioners will ever pray.

Upon motion of the Secretary the report and resolution were unanimously adopted, and the chairman of the committee empowered to forward the same, in proper form, to the Senate and House and to the individual members thereof.

Mr. T. Everett Austin presented a paper on Fast Passenger Locomotives.

Mr. Kenneth Allen presented extracts from a paper by Henry J. Barnes, M. D., on Purification of Sewage by Application to Land, with especial reference to the City of Boston. Efficacy of system is endorsed by numerous authorities.

Mr. W. F. Newell, member of the Civil Engineer's Society of St. Paul, introduced by Prof. Haupt, presented a description of the Borup Coal Chute, which is designed to prevent accidents to pedestrians in street openings, for convenience in receiving or removing material, and for ventilation of cellars and vaults.

PROCEEDINGS OF THE ENGINEERS' CLUB OF ST. LOUIS.—ST. LOUIS, APRIL 29, 1885.—The Club was called to order by Pres. Moore, at the Mercantile Library.

Mr. M. L. Holman read a paper, "House to House Inspection to Prevent Water Waste."

The paper gave a recount of the inspection made in this city from December, 1883, to March, 1884.

A few trials with the Bell Waterphone were made, but it was found that the ordinary iron key used for turning on and off the water at the stop boxes was all that was needed. A portion of the end of the key-rod was flattened out so that the ear could be pressed tightly against it. After some practice this was used with great success.

In order to arrive at the good produced by house to house, combined with night inspection, one district of 118 houses inspected was selected, and 59 houses were all right, while 59 houses were wasting water. Previous to this inspection, all of the houses of this district had been inspected twice by regular day men, and twice by the night gang, followed each time by the day inspection of cases reported for wasting.

The writer concludes that night inspection is a very good method of house to house inspection, as it only puts those who are wasting water to the inconvenience of a day inspection.

The paper was generally discussed.

Mr. C. F. White read a paper on "Dynamometers."

The increase in the practice of selling power, and the growing need of exact information as to the power required for various classes of work, has made a demand for power-measuring machines.

AMERICAN INSTITUTE OF MINING ENGINEERS.—For the annual meeting at Chattanooga, the following papers are announced:

The Relative value of Coals to the Consumer, by H. M. Chance, Philadelphia, Pa.

Quicksilver Condensation at New Almaden, by S. B. Christy, Berkeley, Cal.

Notes on American Blast Furnaces, by John Birkenbine, Philadelphia, Pa.

Supplementary Paper on the No-Bosh Furnace, by W. J. Taylor, Chester, Pa.

The Durham Blast Furnace, by B. Fackenthal, Jr., Riegelsville, Pa.

The New Mining Code of Mexico, by R. E. Chism, Saltillo, Coahuila.

The Manufacture of Steel Castings, by Pedro G. Salom, Thurlow, Pa.

The Flow of Air and Other Gases, by Fred. W. Gordon, Philadelphia, Pa.

A Fire-brick Hot-blast Stove, by Victor O. Strobel. Philadelphia, Pa.

Minerals of the Sequachee Valley, Tenn., by W. M. Bowron, South Pittsburgh, Tenn.

Notes on some American Ore Deposits, by C. M. Rolker, New York City.

The Basic Bessemer Process, by Thomas Egleston, New York City

ENGINEERING NOTES.

QUALITATIVE TESTS FOR STEEL RAILS—BY MR. L. TETMAJER.—This memoir is the first of a series upon the unification of nomenclature and classification of building materials undertaken by the author at the request of the Swiss Engineers' and Architects' Union. For its preparation numerous mechanical tests have been made upon steel rails, both good and bad, taken from the Swiss railways, while the corresponding chemical analyses have been made by Dr. Treadwell in the Polytechnic Laboratory, at Zurich. The results are given for twenty-two examples, about one-half of which have stood well, while the remainder have either broken, split, or suffered considerable abrasion in wear; but in many instances the mechanical test of tensile strength, elongation, and contraction, and the figures of quality (Wohler's sum and Tetmajer's coefficient) deduced from these have varied very considerably for the results obtained in practice. The best wearing rails, which often give contradictory results with the tensile test, were comparatively pure manganese steels, low in silicon, only exceptionally up to 0.2 per cent., but generally below 0.1 per cent., and with less than 0.1 per cent. of phosphorus and sulphur. On the other hand, rails with a tendency to break or split are low in carbon, with variable proportions of manganese, but contain much silicon, 0.3 to 0.9 per cent., and often above 0.1 per cent. of phosphorus. Another series of experiments upon rails for the Finland mines, made by the author in 1879–80, shows the high quality of manganese steel. These are essentially highly carburized (0.3–0.4 per cent. carbon) with 0.7 to 1.4 per cent. manganese, and have stood three and a-half years' wear without a single one being broken; while those of silicon steel with 0.106–0.144 per cent. carbon, 0.592–0.828 manganese, and 0.423–0.435 silicon, have failed in many cases, showing a great tendency to split. In both of the latter instances, however, the figures deduced from tensile tests of both good and bad specimens were substantially the same.

The causes of the difference between the two kinds of steel the author attributes to differences in the structure of the ingot due to the agent used in "chemical consolidation," which may be either manganese or silicon, which structures are illustrated by photographs of ingot fractures. When silicon is used there is a tendency to unsoundness about the exterior of the ingot, which is surrounded by a honeycomb-like cellular casing of greater or less depth; while with manganese the vesicular cavities are more or less dispersed through the whole substance, or concentrated towards the interior of the ingot. Rails made from the former are, therefore, more likely to contain unsound portions near the outer wearing surface, and to give unsatisfactory results in wear, than those from the latter; but as the test pieces are usually cut from the center of the rail-head, the tensile resistance of the inferior may be equal to or surpass that of the superior material.

In summing up his observations the author concludes that the method of tensile testing is mainly of value in determining the quality of the material, but that for the finished product properly arranged falling weight tests are necessary. He also considers that the test pieces should be flat bars of 2.5 to 3.5 centimeters in area, cut as near as possible to the outer surface of both head and foot of the rail. He reprobates especially the research for microscopic imperfections (mikrobensucherei) upon the fractured surfaces, as an annoyance to the producer, and perfectly useless to the consumer.—*Stahl und Eisen.*

IRON AND STEEL NOTES.

FINAL REPORT BEARING UPON THE QUESTION OF THE CONDITION IN WHICH CARBON EXISTS IN STEEL.—The following are the conclusions which Sir Frederick Abel bases on the reports to the Mechanical Engineers:

"The results of the experimental work described appear to warrant the following conclusions in regard to characteristics, recognizable by chemical examination, which are exhibited by different portions of one and the same sample of steel presenting marked physical differences consequent upon their exposure to the hardening, annealing, or tempering processes.

"(1) In annealed steel the carbon exists entirely, or nearly so, in the form of a carbide of iron, of uniform composition (Fe_3C, or a multiple thereof), uniformly diffused through the mass of metallic iron.

"(2) The cold-rolled samples of steel examined were closely similar in this respect to the annealed steel, doubtless because of their having been annealed between the rollings.

"(3) In hardened steel the sudden lowering of the temperature from a high, red heat appears to have the effect of preventing or arresting the separation of the carbon, as a definite carbide, from the mass of the iron in which it exists in combination, its condition in the metal being, at any rate mainly, the same as when the steel is in a fused state. The presence of a small and variable proportion of Fe_3C in hardened steel is probably due to the una-

voidable and variable extent of imperfection, or want of suddenness, of the hardening operation, so that, in some slight and variable degree, the change due to annealing takes place prior to the fixing of the carbon by the hardening processes.

"(4) In tempered steel the condition of the carbon is intermediate between that of hardened and of annealed steel. The maintenance of hardened steel in a moderately heated state causes a gradual separation (within the mass) of the carbide molecules, the extent of which is regulated by the degree of heating, so that the metal gradually approaches in character to the annealed condition; but, even in the best result obtained with blue-tempered steel, that approach, as indicated by the proportion of separated carbide, is not more than about halfway towards the condition of annealed steel.

"(5) The carbide separated by chemical treatment from blue and straw-tempered steel has the same composition as that obtained from annealed steel.

"It does not appear that this inquiry can be further extended with the prospect of obtaining any additional facts—elucidating the condition of the carbon in steel exhibiting various physical characteristics—the value of which would bear any proportion to the very laborious nature of the necessary experimental work which has to be conducted with small quantities of material on account of the necessity of carying out the annealing, hardening and tempering processes with very thin pieces of steel.

"I believe it will be admitted that, although the data obtained have not led to the discovery of a ready chemical method of differentiating between different degrees of temper in steel (a method of examination which Prof. Hughes's interesting results have almost rendered unnecessary), they have at any rate contributed to the advancement of our knowledge of the nature of steel."

THE CLAPP-GRIFFITHS STEEL PROCESS.—At the last meeting of the American Institute of Mining Engineers held at New York City, the contributions of Messrs. J. P. Witherow, of Pittsburgh, and Robert W. Hunt, of Troy, upon the Clapp-Griffiths process of steel manufacture were of great interest. An experimental plant was put up by Messrs. Oliver Bros. & Phillips at Pittsburgh, on the plan of one at Wales. Two thousand tons have been made at these works and sold to the trade with the most favorable results. Mr. Hunt stated that a complete plant, including buildings, with a capacity of 80 gross tons per twenty-four hours, can be erected for $55,000, and that the cost of steel produced by this method varies from $21.95 to $23.10 per ton, according to the quality of pig iron used. With an additional expenditure of $30.000 a blast furnace plant could be equipped with a steelmaking plant, which would take the molten iron from the blast furnace and convert it into steel at an expenditure of $4 per ton, making a product of nearly double the value of pig iron. Such work would leave the puddlers decidedly in the cold, as it costs $12.50 at Pittsburgh to convert a ton of pig iron into muck bar. The most important phase of this new process is the new relation which phosphorus bears to this new product, for this steel with high phosphorus and low silicon gave satisfactory results. A sample containing the following elements:

Carbon	0.08	per cent.
Silicon	0.01	"
Phosphorus	0.50	"
Manganese	0.48	"
Sulphur	0 09	"

gave the following physical results:

Tensile strength	80,940 lbs.
Elastic limit	58,570 lbs.
Elongation	24 per cent.
Reduction of area	$36\frac{4}{10}$ "

This question assumes great importance in view of the fact of the increasing demand for low steels for nails, wire, bolts, agricultural implements, and many other purposes.—*Engineering.*

CLEMANDOT'S METHOD OF TEMPERING STEEL BY COMPRESSION.—By A. CARNOT.—Mr. Clemandot's method consists in heating the metal till it acquires sufficient ductility, and applying great pressure while it cools. This operation modifies the structure of the metal, and imparts to it qualities similar to, though not identical with, those developed by tempering. The resulting metal differs very sensibly from that which is cooled naturally, the grain being much finer, and the hardness and resistance to rupture much greater. Two different and almost simultaneous effects are produced—first, energetic and continuous compression; second, rapid cooling. The latter is caused by contact with the plates of the hydraulic press. Its effect is similar to that produced by cooling in water, while that of the compression resembles the effect of hammering. It is sufficient if the pressure is applied to two faces only. The steel should be heated to a cherry red, and the pressure be brought to the required point (which may be 6, 12, or 19 tons per square inch) as rapidly as possible. In tempering by immersion the volume of the steel is increased and its density diminished, but this is not the case in the new process. The metal becomes very hard without losing its ductility, especially in steels with a large percentage of carbon.

Hitherto there has appeared a slight inferiority in the magnetic properties of the compressed steel, but this is compensated for by other advantages. It is well known that water-tempered steel when re-heated to redness returns almost to its natural state, and loses its magnetic properties. This is not the case with that tempered by compression, which can be re-heated, and even forged, without becoming demagnetized. This steel also retains the fineness of its grain after re-heating. Thus a bar of steel bent into a U-shape and then compressed, and a bar of the same weight compressed when straight, then re-heated and bent at the forge to the same shape as the first, would each support about twenty times its own weight, after having been magnetized to saturation.

It is thought that the magnetic force might be increased by submitting a bar already compressed to a second compression after forging;

and bars that have been compressed may afterwards be tempered in water, and be converted into powerful magnets.

RAILWAY NOTES.

RAILWAY ACCIDENTS COMPARED.—In an article on "Modern Railroad Facilities," contributed by Mr. Barnett Le Van to the *Journal* of the Franklin Institute, the author states that, from railway mortality statistics of England and some parts of the Continent of Europe recently compiled and published in France, it appears that the greatest fatality occurs on the French railways. French railways annually kill one in every 2,000,000; English railways, one in every 5,250,000; Belgian railways, one in every 9,000,000; and Prussian railways, one in every 21,500,000. With reference to injuries, it is stated that French railways wound annually one in every 500,000; English railways, one in every 750,000; Belgian railways, one in every 9,000,000; Prussian railways, one in every 4,000,000. In round numbers, French railways kill five times as many as English, English not quite twice as many as Belgian, and Belgian nearer three times than twice as many as Prussian, which are much the least fatal of the four.

THE ARGENTINE RAILWAYS.—Great progress is being made with the railways of the Argentine Republic, the work of construction being pushed forward with all possible speed. A new section of the Andine line from Mendoza to San Juan, a distance of 95 miles, was completed at the end of March, and was to be opened at once. The entire distance from Rosario to San Juan, 625 miles, is now done in a three-day journey. A few years ago the journey took from twenty to twenty-five days, and the freight by bullock carts was so costly that the products of the Andine province could not be taken to the coast. The railway from Mercedes to Rio Quinto—360 miles—is being pushed forward, and is expected to be ready for traffic this month (May). The Great Northern Railway is rapidly advancing to Salta, a rich agricultural province, distant from Rosario 775 miles. The wealth of that province is stated to have been doubled within the last ten years.

THE work of building the new "island" railway station at Rugby, which is to cost some £70,000, and to be the biggest thing of its kind in Europe, continues to be rapidly pushed forward. Although it is expected that quite another year must elapse before the alterations are completed, yet it is hoped that the down side will be ready for use by about June next. The line has been widened 150 ft. southwards, so as to give room for nine sets altogether of through metals instead of four as now. For the greater safety at the junctions of the new Northampton line of the Stamford branch important works, presenting considerable engineering difficulties have been effected. The traffic will be regulated by large signal boxes at each end of the platform, that at the south end having 180 levers.

MR. P. A. PLEWE, well-known on the Continent as the originator of the large and perfect tramway network, Die Grosse Berliner Pferde-Eisenbahn, and who is also the sole concessionaire of the Brush system of electric lighting for Germany, is now introducing Reckenzaun's system of propulsion on the above-mentioned tramways, and the first of a series of cars is now in course of construction. Mr. Plewe has been in London recently for the purpose of examining the car which is now on the South London lines, and on the strength of favorable reports from independent scientific experts, the permission of the Municipality and the Berliner Pferde-Eisenbahn Gesellschaft was obtained. The first car, which will be fitted internally with unusual elegance, is to be ready for the opening of the Japanese Exhibition next month, and it will be running between the Spittel Market and Bauer's Ausstellungs Park —Alt-Moabit—a distance of about four kilometers, from the city to the west end of the city of Berlin.

ORDNANCE AND NAVAL.

HIGH EXPLOSIVES IN SHELLS.—Some recent experiments upon the use of shells charged with high explosives were recently made by officers of the United States Ordnance Department before the military committee of the United States Senate and a number of members of the foreign legations. Four shots were fired from a range of 1,000 ft. against a precipitous ledge of trap rock. These 6-in shells contained an 11-lb. charge of nitro-gelatine which consisted of 95 per cent. nitro-glycerine and 5 per cent. gelatine, and were exploded by the impact of their concussion against the ledge. The explosions of these shells excavated a cavity in the face of the ledge, throwing the fragments back half a mile in each direction. In view of the effects of this work the local authorities are not willing to permit experiments with shells containing 35-lb. charges, and the experiments will probably be continued at Fortress Monroe. Other army officers have been experimenting on a projectile charged with dynamite, and thrown by condensed air. One of the old fortifications near to New York City is shortly to be dismantled and taken down, and the proposition has been made to test these projectiles upon the old fort. Some of the officers at the torpedo station at Newport, R. I., exploded torpedoes charged with 34 lbs. of gun-cotton, which were placed on the ice of a pond. The explosion is said to have blown holes in the ice 40 ft. across, and thrown ice and water 200 feet into the air.—*Engineering.*

THE Japanese war-ship, Naniwa-Kan, a cruiser recently built by Messrs. Sir W. G. Armstrong, Mitchell, & Co., for the Japanese Government, was designed by Mr. W. H. White, of Elswick, and, like the Esmeralda, has been constructed so as to combine great speed with great offensive power. The Naniwa-Kan and a sister ship, which is nearing completion, are the largest vessels ever built by the Elswick firm, and when delivered to the Japanese Government will be the swiftest and

most heavily armed cruisers afloat. In dimensions the new cruisers are almost identical with the Iris and Mercury, despatch vessels of the Royal Navy, and the Leander class of partially-protected cruisers. They are 300ft. in length, 46ft. in breadth, draw 18½ft. of water, and are of about 3,600 tons displacement. They have twin-screw engines, which are to develop 7,500 horse-power at least, and their estimated speed is from 18 to 18½ knots. The armament includes two 28-ton 26-centimeter guns, mounted on center-pivot automatic carriages, as bow and stern chasers. These heavy guns are worked and loaded by means of hydraulic mechanism, which is an improvement on that fitted in the Esmeralda. On each broadside there are three 15-centimeter guns of 5 tons each, also on center-pivot automatic carriages of Elswick design, and along the broadsides there are also placed no less than ten 1in. machine guns, and two rapid fire-guns. There are two military masts, in the tops of which four of the improved Gatling guns made at Elswick will be mounted. All the guns except those in the tops are carried on the upper deck, and all of them have strong steel shields protecting the guns and crews from rifle and machine gun fire. Besides the gun armament, each vessel will have a complete armament of locomotive torpedoes ejected from four stations—two on each broadside, situated at a small height above water.

SHEFFIELD STEEL FOR HEAVY ORDNANCE.—The Surveyor-General of Ordnance—Mr. Brand—made a statement in Parliament on Monday night which is pleasant reading for Sheffield manufacturers. He said the Government having determined to encourage the production of large steel forging in Sheffield, were now doing as much as possible to give the great Sheffield firms an opportunity of recouping themselves in some degree for their heavy outlay. He assured the House that it was not a question of months, but of weeks, before the Sheffield firms would be in a position to supply large steel forgings for ordnance. Towards this end Messrs. Thomas Firth and Co., Messrs. Charles Cammell and Co., and Messrs. Vickers, Sons, and Co., were making energetic efforts, and in a very short time they would be able to execute any orders with which the Government might favor them. Mr. Brand added that similar efforts had been made by Sir W. G. Armstrong and Co., at Elswick, "so that at the present time forgings of this heavy character would be produced at home entirely to the satisfaction of the Government." Mr. Brand's references to Sheffield are scarcely complete. Messrs. John Brown and Co. are also exhibiting similar enterprise, and are well forward with their work. The particular direction in which the extensions are being made is not in the putting down of heavier hammers for the manipulation of large masses of steel, but in the erection of forging presses, which are believed to be more advantageous in dealing with great ingots. The four Sheffield firms mentioned are at present expending at least £200,000 to £250,000 on new forging presses, with the necessary adjuncts of powerful cranes, furnaces, &c. Messrs. Vickers, Sons, & Co., are about ready for operations. Messrs. Cammell and Co. are erecting a special building to hold their press. Messrs. John Brown and Co. are able to utilize their rail mill. There is not the slightest doubt of the Sheffield manufacturers being able to do all that ts required of them in the future as they have done in the past. According to Sir Thomas Brassey, the Government is preparing to spend on shipbuilding £3,000,000, or double the amount placed at the disposal of any other naval administration, their scheme for the strengthening of the Navy including four ironclads, five belted cruisers, torpedo ram, eight scouts, five gun vessels, and fifteen torpedo boats, of which ten were to be ordered at once. This list implies a good deal of work in steel, but it is altogether exclusive of the heavy ordnance needed, not only for arming ships, but for land defences. It is chiefly for these monster guns that the Sheffield firms are at present expending money so freely. It should not be forgotten that Mr. John Haswell, formerly locomotive superintendent of the Austrian State Railways, was the originator of the forging press, and for many years he has used his presses on a large scale and with perfect success in Vienna.—*Engineer*.

DYNAMITE SHELLS.—The *San Francisco Chronicle* gives an account of the recent experiments with dynamite shells at Port Lobos. It quotes General Kelton as saying of them: "The experiments were made under my charge, and with the authority of the chief of ordnance. The piece of ordnance used was a condemned 3-inch rifle gun, made of wrought iron; the gun was a sound one, save that it had become honeycombed by use and exposure to weather; it was a good gun for the experiments. I was ably assisted by Mr. Quinan, officer of the 4th United States Artillery, who resigned to undertake the hazardous business of improving the methods of manufacture of high explosives, for which task his scientific attainments eminently fitted him. Experiments of the kind in question need the supervision of an expert in high explosives, and Mr. Quinan's knowledge of dynamite came into great service. Mr. Quinan in person loaded the shells, each shell, an elongated 3-inch rifle projectile, being charged with 7 oz. of dynamite. The selected place of experiment was Lobos Beach, with the ocean on one side and a precipitous cliff on the other, the place being selected so that no possible danger could occur to any one. When the gun was fired, our party was over 100 yards from the piece, and under protection. The gun was placed in position 150 yards in front of a huge rock. The first projecting charge was a ¼ lb of cannon powder. The rock was struck by the shell, the dynamite ignited by percussion, and the shell broken into innumerable fragments, whereas by ordinary powder it would only have broken into a few large fragments. The second charge was ½ lb. of cannon powder, and the experiment was attended with equally good results. It did just what was expected; the shell was expelled, and did not ignite until it struck the rock. The

third charge was a pound of powder, service charge. When the gun was fired, the explosion of the charge, the bursting of the shell, and the shattering of the gun, appeared to be simultaneous. The gun was torn into fragments. One fragment, including the breech, and weighing about 200 lbs., was hurled to the rear fully 20 feet; the muzzle part hung to the carriage by a trunnion, the carriage being only slightly injured; the third fragment of the gun, weighing several hundred pounds, flew high in the air in a nearly vertical course and over the cliff; the immense piece of iron went up fully 90 feet. Then, as a matter of course, our experiments for the day ceased." The results of the experiments were, in the opinion of General Kelton, "exceedingly satisfactory, for they conclusively showed that shell loaded with dynamite can be used in warfare. Seven ounces of dynamite rent the gun as a charge of 100 lbs. powder could not have done. Powder would have opened a fissure in the iron, thus permitting the gas generated by its combustion to escape; but while the combustion of powder, while rapid, is progressive, the combustion of dynamite is so instantaneous that the enormous volume of gas thereby generated seems to want to escape at once. This fact was shown by the sudden rending of the gun into fragments. If the dynamite shell should strike the side of the vessel and explode without penetrating the armor, the destructive effect would be greatly in excess of the damage worked by the ordinary shell made of gunpowder. But the dynamite shell must penetrate to some extent to produce its full effect. I am satisfied that experiments will show that it can easily be managed to give the shell the power to thus penetrate before it explodes. The necessary penetration—about one-half the length of the shell, would be effected in the thousandth part of a second after it had reached the ship. Then the exploding dynamite would instantaneously rend asunder the entire side of an ironclad. In defending a fort against a land attack these dynamite shells would be very effective. One of these shells exploding in the midst of a body of attacking troops would produce as much consternation as a thunderbolt; its explosion would be like unto the explosion of a powder magazine in their very midst. No troops in the world, however brave, could stand more than a few of such shells. So destructive, in fact, would be these shells that their introduction in active warfare would vastly diminish the duration of wars, if it did not make wars an impossibility." In conclusion, General Kelton expressed satisfaction that the experiments had been so successful. While experiments had been made by others, he did not think that any had gone so far or succeeded so well. Captain Daniel M. Taylor, of the ordnance department, and an aide-de-camp on General Pope's staff, said: "The experiments conducted so successfully by General Kelton show that a compound many times more destructive than gunpowder will add to the havoc of the battlefield in future wars. One peculiar property of dynamite may somewhat interfere with its usefulness as a destroying and rending agent, and that is the fact, authenticated by experiments, that its destroying power operates vertically and with its main effect in a downward direction; in other words, a dynamite-charged shell would not scatter death and destruction in every direction, as a gunpowder-charged shell so frequently does." Captain James Chester, of the 3d Artillery, has paid great attention to the subject of dynamite in its connection with the art of war. He maintains that dynamite can be used with great success in active warfare if rockets are employed to throw the death-bearing material into the ranks of the enemy. He holds that dynamite shells can be thrown by means of the rocket with fair accuracy and to very long ranges. He calls these rocket-propelled shells aerial torpedoes, in contradistinction to submarine torpedoes, and holds that, with the submarine torpedo defence of the navy, and the aerial defence in the hands of the army, the country would be safe against any attack.

BOOK NOTICES

PUBLICATIONS RECEIVED.

MONTHLY Weather Review for March. 1885. Washington: Signal Office.

The Popular Science Monthly—June. New York: D. Appleton & Co.

Transactions of the American Institute of Mining Engineers (advanced sheets).

Oxygen and Ozone. By Prof. Anton Stamm.

THE COPPER-BEARING ROCKS OF LAKE SUPERIOR. By ROLAND DUER IRVING. Washington: Government Printing Office.

This is one of the component parts of the general report of the United States Geological Survey under Clarence King.

The separate chapters of this elegant quarto volume present, with fine illustrations and maps, the following:

Extent and General Nature of the Keweenaw Series, Lithology of the Keweenaw Series, Structural Features of the Three Classes of Rocks of the Series, General Stratigraphy of the Keweenaw Series, The Keweenawan Rocks of the South Shore of Lake Superior, The Keweenawan Rocks of the North and East Shores of Lake Superior, Relations of the Keweenawan Rocks to the Associated Formations, Structure of the Lake Superior Basin, The Copper Deposits.

Colored lithographs of Microscopic rock sections form a conspicuous feature of the book. The folding maps and geological sections are also beautifully colored.

REPORT OF THE COMMISSIONER OF NAVIGATION FOR 1884. Washington: Government Printing Office.

The present report contains for a preface the law establishing the Bureau of Navigation.

Then follows the report proper, including a historical retrospect of the birth and growth of the maritime commerce of our country. A brief account of the merchant marine of France, of Norway, and of Italy then follows. Then, in order, are presented a statistical account of the lake and ocean commerce of the United States, the English Law (regarding seamen), the French Law, the German Law, the Norwegian

Law, the Italian Law, the Belgian Law, the Netherlands Law, Pilotage in United States Ports, the Laws Governing Coasting Trade of the above-mentioned countries, and the Law Governing Collisions at Sea.

A tabulated statement of tonnage of the United States Merchant Marine closes the report.

APPLIED MECHANICS. By GAETANO LANZA, S. B., C. E. New York: John Wiley & Sons.

As Prof. Lanza explains in his preface, "the work is essentially a treatise on strength and stability; but inasmuch as it contains some other matter, it was thought best to call it Applied Mechanics, notwithstanding the fact that a number of subjects usually included in treatises on Applied Mechanics, are left out."

What the work does contain may be substantially inferred from the list of topics, to each of which a chapter is devoted:

I. Composition and Resolution of Forces. II. Dynamics. III. Roof Trusses. IV. Bridge Trusses. V. Center of Gravity. VI. Strength of Materials. VII. Strength of Materials as determined by Experiment. VIII. Continuous Girders. IX. Equilibrium Curves; Arches and Domes. X. Theory of Elasticity and Applications.

When it is added that the text of these ten chapters covers seven hundred and twenty pages octavo, it will seem to the reader that the topics are treated with something more than ordinary fullness In short, we believe the work is admirably adapted for use as a text-book for students in engineering. Of course the omissions referred to by the author must be supplied from other sources before the pupil can complete Applied Mechanics, but within the range of topics specified above, we know of no book better adapted to the wants of American students than this.

BALLOONING. By G. MAY. London: Symans & Co. New York: D. Van Nostrand.

This neatly-printed little volume presents a concise sketch of the history of ballooning, and discusses the obstacles that inventors have sought to overcome.

The scientific researches that have been conducted by aid of balloons receive a fair share of attention under the heading of Practical Applications of Aeronautics. This would presumably include the military use, but the author has devoted a separate chapter to this phase of practical use.

More space, however, is devoted to the prospective service of balloons when adequate steering power shall have been devised.

The author concludes, "It would be venturesome to assert that aerial navigation has no future, looking to what it has accomplished during the past century. Nevertheless, considering the wonderful strides art and scientific progress have made in later years, it is quite within the scope of discovery to contrive some appliance partly to effect a more practical solution of the difficult problem of balloon steering."

COMSTOCK MINING AND MINERS. By ELIOT LORD. Washington: Government Printing Office.

This report forms Monograph No. 4 of the United States Geological Survey. "It is," says the preface, "the record of a struggle which has materially affected the mining interests of the world. It is the story of the birth of the silver mining industry in this country, and it portrays, as well, the most vigorous growth of that industry. The simple narrative is, in truth, not less marvelous than an Arabian tale, recounting, as it does, how a handful of earth tossed away carelessly by a poor immigrant became the loadstone which drew a swarm of men to a desert avoided even by beasts, and how from this clue a thread of gold was traced to its hidden source, and treasures rivaling the fancied store of Aladdin were unveiled.

The history, though encumbered here and there with dry details of legal and commercial transactions, fulfills the promise implied in the preface.

Three well-engraved maps embellish the work.

MISCELLANEOUS.

THE New South Wales shale yields, on an average, about 150 gallons of crude oil per ton, which contains over 60 per cent. of refined kerosene oil, and the remaining products consist of gasoline, benzine, spongaline, paraffine, wood-preserving composition, and lubricating oil. Its gas-producing capabilities amount to the large yield of over 18,000 cubic feet of gas, with an illuminating power of 38 to 40 candles. On this account it has been found advantageous for mixing with ordinary coal in the manufacture of gas.

ENGLISH COAL IN RUSSIA.—A short time ago the managing engineer of the South-West Russian Railroad sent in a report to the directors of the line, stating that the English coal supplied for the use of the locomotives was of a very inferior quality, and recommending the adoption of certain measures; among others, the dispatch of an agent to England, to investigate matters, in order to put an end to the evil. In reply, according to the Odessa papers, the directors have declared the adoption of any special measures unnecessary, since they intend shortly to suspend the use of English coal on the line. Whether Russian coal, or petroleum refuse, is to be used instead, the directors do not say; thus leaving the matter open for the newspapers to fight about. Some assert that Russian coal from the Donetz Valley is to be used on all the lines stretching from the Black Sea to the Austrian frontier; others, that the South-West Railway Company dislike the native fuel even more than the English, and are determined to adopt the practice of the Volga lines, and burn petroleum refuse.

AT a recent meeting of the Cambridge Philosophical Society, a communication was made on the measurement of electric currents, by Lord Rayleigh. The author referred to the method of measuring currents by the silver

voltameter as suitable for currents of from .05 amperes to 4 amperes, and stated that the electro-chemical equivalent of silver, as determined at the Cavendish Laboratory, was 1.119×10^{-2}. A second method was described, suitable for larger currents. It consists in balancing the difference of potential between two points in the circuit through which the current is running against the effects of a standard cell working through a large resistance, such as 10,000 ohms. The author suggested, as a third method, the use of the rotation of the plane of polarization of light passing through a piece of heavy glass, around which the current circulates in a coil of thick wire. A current of 40 amperes will produce a rotation of 15 deg. if the coil have one hundred turns.

At a recent meeting of the Paris Academy of Sciences, a note on "The Universal Hour Proposed by the Conference in Rome," was communicated by M. Faye. The author urged several objections against the adoption of Greenwich astronomical time and meridian, calculating the longitude from 0 to 24 h. east, which might be convenient for navigation and astronomical purposes, but unsuitable for railways, telegraph, government offices, and the public generally. For the formula, universal time=local time−(L+12 h.), where L indicates the longitude calculated east from Greenwich, he proposes to substitute, universal time=local time−L. The formula would thus be simplified by the suppression of the last term, and, instead of Greenwich astronomical time, the civil hour would be adopted as the universal hour. Thus would be avoided the inconvenience of disagreement between local and universal time, which would otherwise be felt precisely in the most densely-peopled regions of the globe.

At a recent meeting of the Chemical Society, a paper was read on "Toughened Filter-paper," by E. E. H. Francis. Filter-paper which has been immersed in nitric acid, rel. den. 1.42, and washed with water, is remarkably toughened, the product being pervious to liquids, and quite different from parchment paper made with sulphuric acid. Such paper can be washed and rubbed without damage, like a piece of linen. The paper contracts in size under the treatment, and the ash is diminished; it undergoes a slight decrease in weight, and contains no nitrogen. Whereas a loop formed from a strip 25 mm. wide of ordinary Swedish paper gave way when weighted with 100—150 grams, a similar loop of toughened paper bore a weight of about 1.5 kilogs. The toughened paper can be used with the vacuum pump in ordinary funnels without extra support, and fits sufficiently close to prevent undue access of air, which is not the case with parchment paper. An admirable way of preparing filters for the pump is to dip only the apex of the folded paper into nitric acid, and then wash with water; the weak part is thus effectually toughened.

Mr. Thomas Kay, of Stockport, lately read a paper before the Manchester Literary and Philosophical Society in which he suggested a method of making sea-water potable by precipitation. He suggests that every ship's boat should be supplied with a quantity of citrate of silver, which should be used for precipitating the chlorides, leaving the sodium, potassium, magnesium, and other constituents in solution as citrates. The solution would be similar to ordinary effervescing draughts after the gas has escaped; it would be slightly aperient or slightly diuretic if taken in too large quantities, but still suitable for moistening the parched mouth. The expense of the silver would be but a small addition to the capital sunk in a ship, and the interest on it would be a small insurance premium against thirst in case of disaster. The value of the silver would not decrease, and could always be realized if disaster did not occur. The scheme seems practicable if the solution of citrates is sufficiently weak to be potable; only experience can prove this. The silver, being very portable, not easily identified, and easily reduced to metallic silver, would offer great temptations to petty larceny.

"Improvements in the Manufacture of Cement" forms the subject of a good deal of recent patent literature. Mr. R. Stone's improvement in the process of manufacture consists essentially in grinding the materials in a red-hot state, giving a better prepared material with less consumption of power. The burnt clinkers pass red-hot through steel-crushing rolls of special construction, and thence to the grinding rollers, the bed-plate of which is made concave and adapted to the lower roll, so that the crushed material after passing between the rollers is further ground between the lower roll and the bed-plate. Mr F. W. Gerhard adds lime to certain impure silicates of alumina and iron, and claims to make cement from the rotch bat or bovin, and what is known as black lime in the Wolverhampton district. Mr. E. W. Harding claims the application of gaseous fuel, in kilns of special construction, to the burning of Portland cement, together with the utilization of the waste heat, for the carbonization of coal and the heating of the drying floors; also the mixing of a certain proportion of resin with the cement mixtures to assist the calcination. Messrs. R. W. Lesley and J. M. Wilcox seek to mould cement powder into forms suitable for the kilns, as respects size, adaptability to free draught, and the like, while dispensing nearly, if not altogether, with the water ordinarily required to bring it to the pasty condition for this purpose. They compress the powdered materials, damped by heavy pressure between rollers having cells or cavities wherein the powder is molded into blocks of the requisite size. Messrs. J. W. Matteson, W. J. Chapman, and T. G. Matteson seek to improve the quality of the mixture of chalk, clay, and water in cement making, technically known as slurry, and obtain at a particular stage of the manufacture a more complete admixture and homogeneity of the materials, with perfect disintegration, and free from small particles of chalk hitherto met with in all known processes of manufacture. The apparatus consists of a rotary sieve or tempse, preferably of conical shape, revolving in a well provided with an exit pipe at one end.